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U.S. Army
Environmental
Center

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U.S. ARMY ENVIRONMENTAL CENTER

MILAN ARMY AMMUNITION PLANT

Focused Feasibility Study For the Northern Industrial Area Soil

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FINAL DOCUMENT

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Focused Feasibility Study for the Northern Industrial Area Soil
for
Task Order No. 2
Milan Army Ammunition Plant

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TABLE OF CONTENTS

Section *Page*

TABLE OF CONTENTS (Continued)

Section *Page*

TABLE OF CONTENTS (Continued)

Section *Page*

TABLE OF CONTENTS (Continued)

Section *Page*

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

1,3-DNB - 1,3-dinitrobenzene
2,4-DNT - 2,4-dinitrotoluene
2,6-DNT - 2,6-dinitrotoluene
1,3,5-TNB - 1,3,5-trinitrobenzene
2,4,6-TNT - 2,4,6-trinitrotoluene
2,4-D-6-NT - 2,4-Diamino-6-Nitrotoluene
4-A-2,6-DNT - 4-Amino-2,6-Dinitrotoluene
2,6-D-4-NT - 2,6-Diamino-4-Nitrotoluene
2-A-4,6-DNT - 2-Amino-4,6-Dinitortoluene

ADA - Ammunition Destruction Area
ARARs - Applicable or Relevant and Appropriate Requirements
CCLT - Clean Closure Leaching Test
CDIs - chronic daily intakes
CEQ - President's Council on Environmental Quality
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
C_{max} - maximum concentration
CRL - Certified Reporting Limit
CSF - Cancer Slope Factor
DRE - destruction and removal efficiency
dscf - dry standard cubic foot
ERM - Environmental Resources Management, Inc.
FEMA - Federal Emergency Management Agency
FS - Feasibility Study
ft-msl - feet-mean sea level
GOCO - government-owned, contractor-operated
HMX - cyclotetramethylene tetranitramine
HPLC - High Performance Liquid Chromatography
HSWA - Hazardous and Solid Waste Amendments
i - hydraulic gradient
ICF - ICF Kaiser Engineers
ISV - in-situ vitrification
IWWTF - Industrial Waste Water Treatment Facility
K - hydraulic conductivity
LAAP - Louisiana Army Ammunition Plant
LAP - Loading, Assembling, and Packaging
LDRs - Land Disposal Restrictions
MAAP - Milan Army Ammunition Plant
MAIV - mechanically agitated in-vessel
MOD - Milan Ordnance Depot
mph - miles per hour
NAD - Naval Ammunition Depot
NB - Nitrobenzene
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
N_e - effective porosity
NPDES - National Pollution Discharge Elimination System
NEPA - National Environmental Policy Act of 1969
O&M - operation and maintenance
OBG - Open Burning Grounds
ORNL - Oak Ridge National Laboratory

OU - Operable Unit
PAHs - polynuclear aromatic hydrocarbons
PCBs - polychlorinated biphenyls
POHCs - principal organic hazardous constituents
RCRA - Resource Conservation and Recovery Act
RDX - cyclotrimethylene trinitramine
RfD - Reference Dose
RI - Remedial Investigation
RME - reasonable maximum exposure
ROD - Record of Decision
SADA - Savanna Army Depot Activity
SARA - Superfund Amendments and Reauthorization Act of 1986
SITE - Superfund Innovative Technology Evaluation
SWMUs - solid waste management units
TAL - Target Analyte List
TBC - to-be-considered
TCL - Target Compound List
TCLP - Toxicity Characteristic Leaching Procedure
TDEC - State of Tennessee Department of Environment and Conservation
tetryl - N-methyl-N,2,4,6-tetranitroaniline
TSD - treatment, storage, and disposal
UMDA - Umatilla Army Depot Activity
USAEC - U.S. Army Environmental Center
USEPA - United States Environmental Protection Agency
V - Groundwater flow velocity
VHS - Vertical and Horizontal Spread
VOCs - volatile organic compounds
WCOP - Wolf Creek Ordnance Plant
Δh - change in hydraulic head
Δl - change in distance

1.0 INTRODUCTION

ICF Kaiser Engineers (ICF) and Environmental Resources Management (ERM) have been contracted by the U.S. Army Environmental Center (USAEC) to perform a Focused Feasibility Study (FS) for contaminated soil within the northern industrial areas of Milan Army Ammunition Plant (MAAP), Tennessee. This work is being performed under Contract No. DAAA15-91-D-0014, Task Order 2. The purpose of the Focused FS is to develop and evaluate remedial alternatives such that an appropriate remedy can be selected for the site.

The MAAP Remedial Investigation (RI) performed in 1989-1991 (USAEC, 1991a) confirmed that the O-Line Ponds area, facility drainage ditches that received industrial wastewater, and manufacturing and disposal areas have been sources of groundwater contamination. One finding of the RI Report was that sufficient information was available concerning the O-Line Ponds area to proceed with a Focused FS. The O-Line Ponds area was further divided into two operable units (OUs): OU1 is the groundwater immediately downgradient of the O-Line Ponds area, and OU2 is the soil, surface water, and sediment at the O-Line Ponds area. A Proposed Plan and Record of Decision (ROD) for OU1 were finalized in 1992, which called for groundwater extraction, treatment, and reinjection of the treated water upgradient of the O-Line Ponds. The design of this system was completed in 1993, and construction of the system is currently underway. For OU2, the Proposed Plan and ROD (finalized in 1993) called for the extension of the existing multi-layered cap to cover the contaminated soil around the perimeter of the existing cap. The design of the cap extension was completed in 1994, and construction will begin in late 1994.

At the same time that work began at the O-Line Ponds area, additional work began in evaluating the residual contamination in the northern ditches and the off-post groundwater on the west side of the facility. This investigation has led to the Army's decision to fund the effort to design and build a substitute water supply system for the City of Milan.

In addition, an investigation of the southern study areas (consisting primarily of the Open Burning Ground (OBG) and the Ammunition Destruction Area (ADA)) began in the spring of 1994. These investigations will lead to the development of Focused FS reports and decisions regarding remediation of the contaminated areas.

An investigation of the source areas within the northeastern portion of the facility (designated as OU3) began during the summer of 1993. This general investigation of the OU3 area has led to a focused study of Line B (the field work was performed during the summer of 1994) and the northern facility boundary within OU3. At the northern boundary of OU3, explosives compounds have been detected at increasing levels in the groundwater, and these contaminants are migrating off site. As a result of the northern boundary study, a Proposed Plan and ROD were published in late 1994 that calls for extraction and treatment of off-site groundwater. The Focused FS report for the Line B investigation will be published in early 1995.

This Focused FS Report addresses the explosives-contaminated soil within the northern industrial areas, which consists of the load lines and disposal areas in the northern portion of MAAP. Although the areas of contaminated soil within these areas have not been fully defined, this Focused FS presents an approach for identifying areas of explosives-contaminated soil requiring remediation. When these areas are remediated, the residual risk posed to human health and the environment will be reduced to levels within the U.S. Environmental Protection Agency (USEPA) target risk range. This Focused FS identifies and screens remedial technologies potentially capable of remediating the soil that is removed from the northern industrial areas.

The specific project tasks included in this report are the following:

- Remedial action objectives have been developed for the specific contaminants, affected media, and exposure pathways;

- Remedial technologies have been identified which, alone or in combination, can treat, contain, or dispose of contaminated media;

- The remedial technologies have been screened to eliminate those that are not technically implementable, based either on non-attainment of chemical-specific requirements or on the volume of media which must be treated;

- As required under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), the remedial technologies have been assembled into remedial alternatives which, to the maximum extent practicable, utilize permanent solutions and alternative technologies; and

- A detailed analysis of the remedial alternatives has been performed using the nine evaluation criteria listed in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

This Focused FS has been conducted in accordance with USEPA guidance documents which govern activities performed under CERCLA, as amended by SARA, and as implemented by the NCP, 40 CFR 300; and the President's Council on Environmental Quality (CEQ) regulations (40 CFR 1500-1508).

1.1 ORGANIZATION OF REPORT

This report contains eight sections, as follows:

Section 1.0 - Introduction
The purpose of the Focused FS and organization of the report are presented.

Section 2.0 - Site Background
The site background and the results of previous investigations, including the RI and all relevant follow-on work, are presented. The discussion focuses on the results relevant to the northern industrial areas.

Section 3.0 - Remedial Action Objectives
Remedial action objectives are identified for explosives-contaminated soil at the northern industrial areas. These remedial action objectives include risk-based remediation goals for contaminants in the soil.

Section 4.0 - Identification of General Response Actions
General response actions that are applicable to the areas of concern are identified. These general response actions are broken down into technologies and process options, which are screened based on implementability, effectiveness, and order-of-magnitude cost.

Section 5.0 - Development of Remedial Alternatives for Soil
Remedial alternatives for contaminated soil are developed by combining the remedial technologies that remain after screening.

Section 6.0 - Detailed Evaluation of Remedial Alternatives
Using the nine criteria identified in the NCP (40 CFR 300.430(e)), each remedial alternative is evaluated in detail.

Section 7.0 - Comparison of Remedial Alternatives
Based on the results of the detailed evaluation, the remedial alternatives are compared based on the nine evaluation criteria.

Section 8.0 - References

2.0 SITE BACKGROUND

The following section presents information regarding MAAP and, specifically, the northern industrial areas. This includes information on the site history, physical setting of the area, and a summary of potential environmental problems identified at the site based on previous investigations.

2.1 PHYSICAL SETTING

2.1.1 Location

MAAP currently covers 22,436 acres and is situated in both Gibson and Carroll Counties in western Tennessee (see Figure 2-1). The City of Milan lies 5 miles west of MAAP and has a population of 8,100; Humboldt lies 17 miles southwest with a population of 10,200; Trenton lies 18 miles northwest with a population of 4,600; and Jackson lies 28 miles south with a population of 50,000. The site is located approximately 60 miles east of the Mississippi River.

2.1.2 Climatology

The MAAP area is characterized by a temperate and continental climate. Rainfall averages about 50 inches per year, with an average minimum of 2.9 inches in October and an average maximum of 6.0 inches in January. There is no dry season. Snowfall can be highly variable from year to year. The average annual evaporation is approximately 40 inches, and relative humidity averages 60-70%. The monthly mean temperature ranges from 40°F in winter to 80°F in July. The average frost free season is 215 days per year. The average depth of frost is 3 inches, with an extreme depth of 10 inches. Prevailing winds are from the south at an average velocity of 6-10 miles per hour (mph).

2.1.3 Site Physiography and Topography

MAAP lies within the Gulf Coastal Plain physiographic province of the Mississippi Embayment, west of the western valley of the Tennessee River and east of the Mississippi River valley. The topography of the site and surrounding area is gently rolling to flat. It slopes regionally westward and contains numerous small streams, creeks, and drainage ditches. The elevation of the plant varies from a high of approximately 590 feet above mean sea level (ft-msl) on the south side to a low of approximately 320 ft-msl on the north boundary of the plant.

2.1.4 Site Geology

The surface soil at MAAP (to a depth of about 2 feet) consists chiefly of a reddish-brown to yellow mottled silty clay that grades into a clay unit with depth. The soil types include the Memphis, Loring, Henry, Falaya, and Waverly soil associations. The Memphis and Loring series occur on higher elevations and is a well-drained soil. The Henry soil series is somewhat poorly drained and is usually associated with flat terrain while the Falaya and Waverly occur in the low areas and are poorly drained.

The surface alluvium encountered at MAAP ranges in thickness from 10 to 20 feet. The alluvium consists of a yellowish-brown to strong brown loamy, silty, clay. The silty clay is loose to moderately stiff with low plasticity, and contains varying amounts of organic material.

The hydrologic unit below the surface alluvium is the Memphis Sand in the Claiborne Group of Tertiary age. The Memphis Sand consists of a thick body of sand that includes thick beds of clay and

FIGURE 2-1
Location of MAAP in Western Tennessee

silt. The sands in the Memphis Sand range from very fine- to very coarse-grained, but are commonly fine-to-medium and medium-to-coarse grained. The color of the sands varies, but is predominantly white, brown, yellow or gray with minor occurrences of reddish-yellow to red sands occurring as thin bands within the more common sand zones. The sand is thick-bedded, with grain sizes varying vertically as well as laterally. Thin layers of indurated rock fragments were encountered during drilling at MAAP and are probably erosional lag deposits from an iron-cemented sandstone source. Subordinate lenses or beds of clay and silt are present at various horizons, and these clay and silt lenses vary in thickness. During drilling activities conducted as part of the RI (USAEC, 1991a), most of these lenses were observed to be 0.04 to 0.5 feet thick. The clay and silt locally are carbonaceous and lignitic; thin lenses of lignite also occur locally.

The Flour Island Formation of the Wilcox Group is the lower confining unit for the Memphis Sand and consists predominantly of clay and silt (Parks and Carmichael, 1990). The thickness of this unit beneath the Milan area is estimated to be 50 feet, based on interpolations from regional cross-sections (Parks and Carmichael, 1990). It is believed that this unit was encountered at a depth of 245 feet at a borehole on the northern border of MAAP.

The exact depth to rock under MAAP is not known. A test well drilled to 1,289 feet about 20 miles south-southwest of MAAP near Jackson, Tennessee, was stopped in a sandy clay marl. It was estimated that rock (possibly limestone) would be encountered between 500 to 800 feet below the drilled depth of the test well.

East-west and north-south cross-sections were developed from the well boring logs of monitoring wells installed at MAAP during the RI (Figures 2-2 and 2-3). The locations of the monitoring wells on which these cross-sections were based are shown on the site map (Figure 2-4). Split spoon samples were collected at five-foot intervals from the shallow and deep monitoring well borings at cluster well sites. The lithologic logs from these wells were combined to form a composite stratigraphic column for the site. Other stratigraphic columns were constructed from the boring logs of single wells. The split spoon samples collected are lithologically representative of a two-foot interval within a five-foot drilling interval. The stratigraphic columns illustrate a continuous lithology based on the samples collected and observations recorded during drilling of the borehole. For example, a split spoon sample containing sands from the 20 to 22 foot depth interval was considered continuous if the sands were also recovered in the split spoon sample from the 25 to 27 foot depth interval. If a clay zone was encountered and observed in the drill cuttings during drilling from 20 to 25 feet, the depth and approximate thickness of the clay unit was noted on the boring log.

The cross-sections (Figures 2-2 and 2-3) indicate that the lithology varies both vertically and laterally over short distances. Wells MI057 and MI058 are 800 feet apart, and from the stratigraphic columns shown in Figure 2-2, it is evident that the occurrence and thickness of the clay zones changes considerably over short distances. Therefore, correlation of stratigraphic units has not been attempted because of the lateral variations in lithology and absence of laterally continuous and recognizable stratigraphic units.

2.1.5 Site Hydrogeology

The major controls on groundwater movement in the unconfined aquifer underlying MAAP are the dip of the sediments, surface topography, and surface recharge and discharge patterns. Groundwater flow in the MAAP area is generally to the west, in the direction of regional dip of these sands, and also trends northerly because of the topographic influence. The dip of the sands is about 20 feet/mile to the northwest. On a general scale, there are no abrupt hydrologic boundaries in the aquifer. The clay lenses and clay rich zones may locally alter vertical groundwater flow, and stratification of the sediments tends to make vertical conductivities lower than horizontal conductivities.

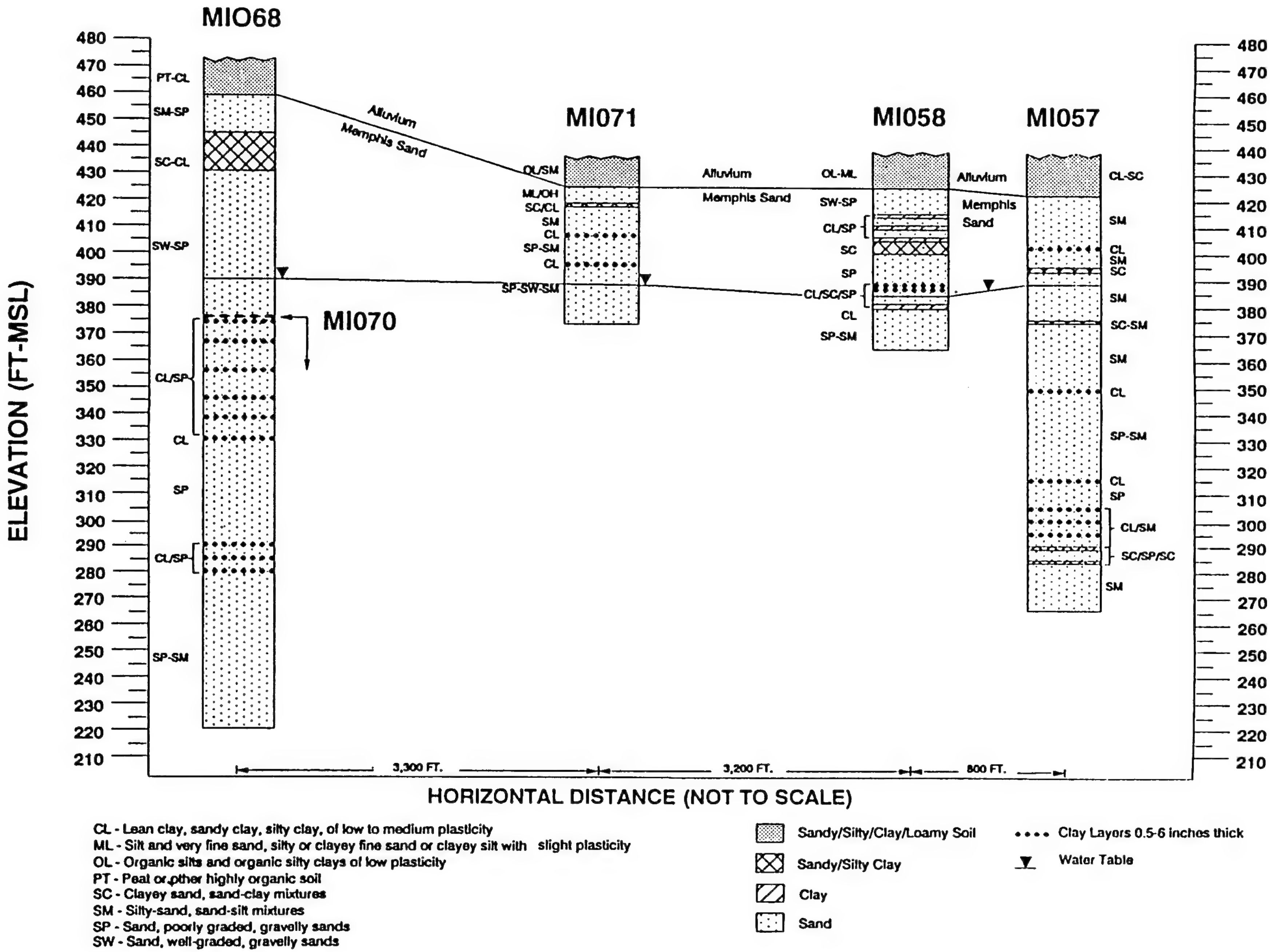
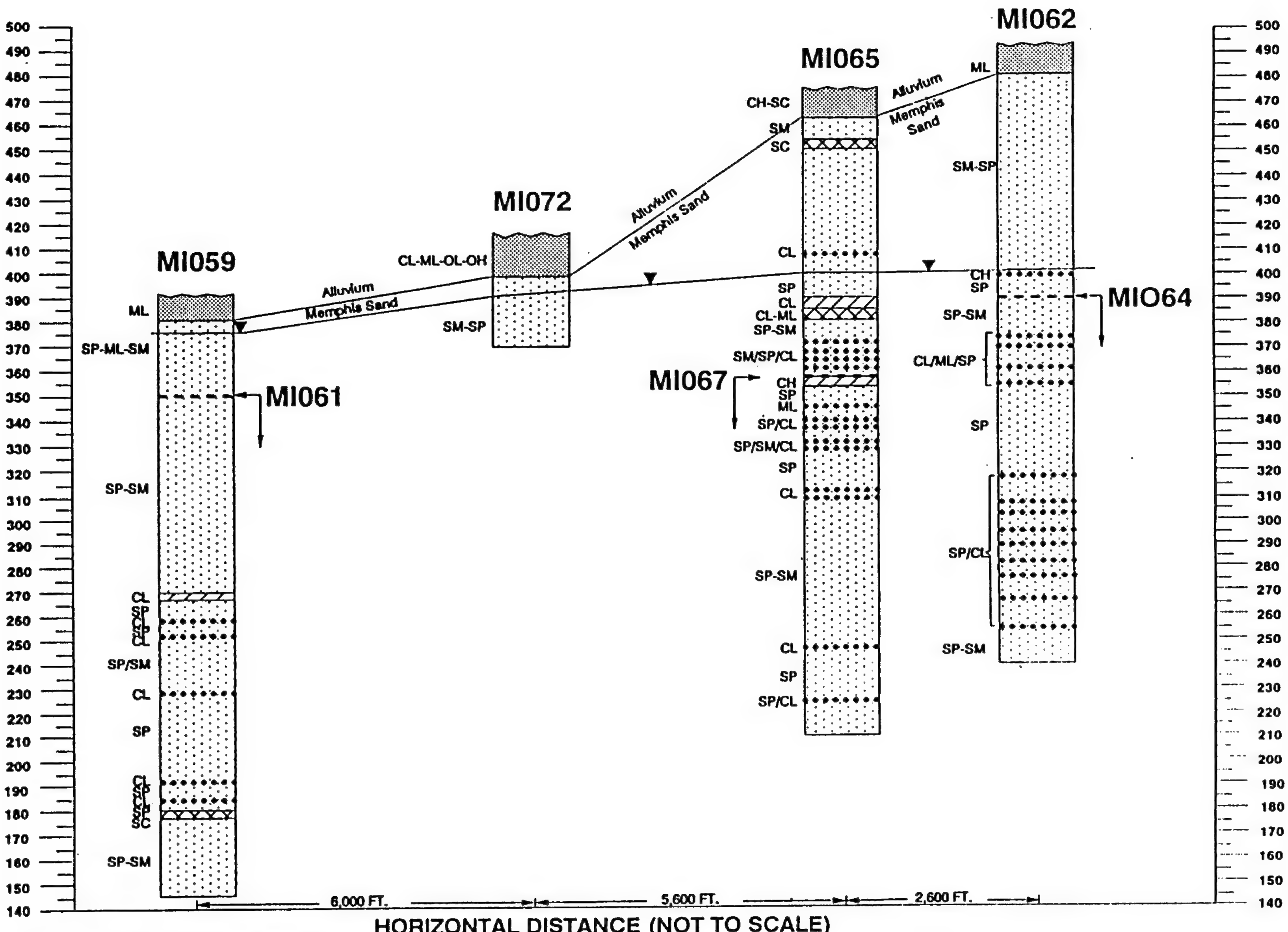


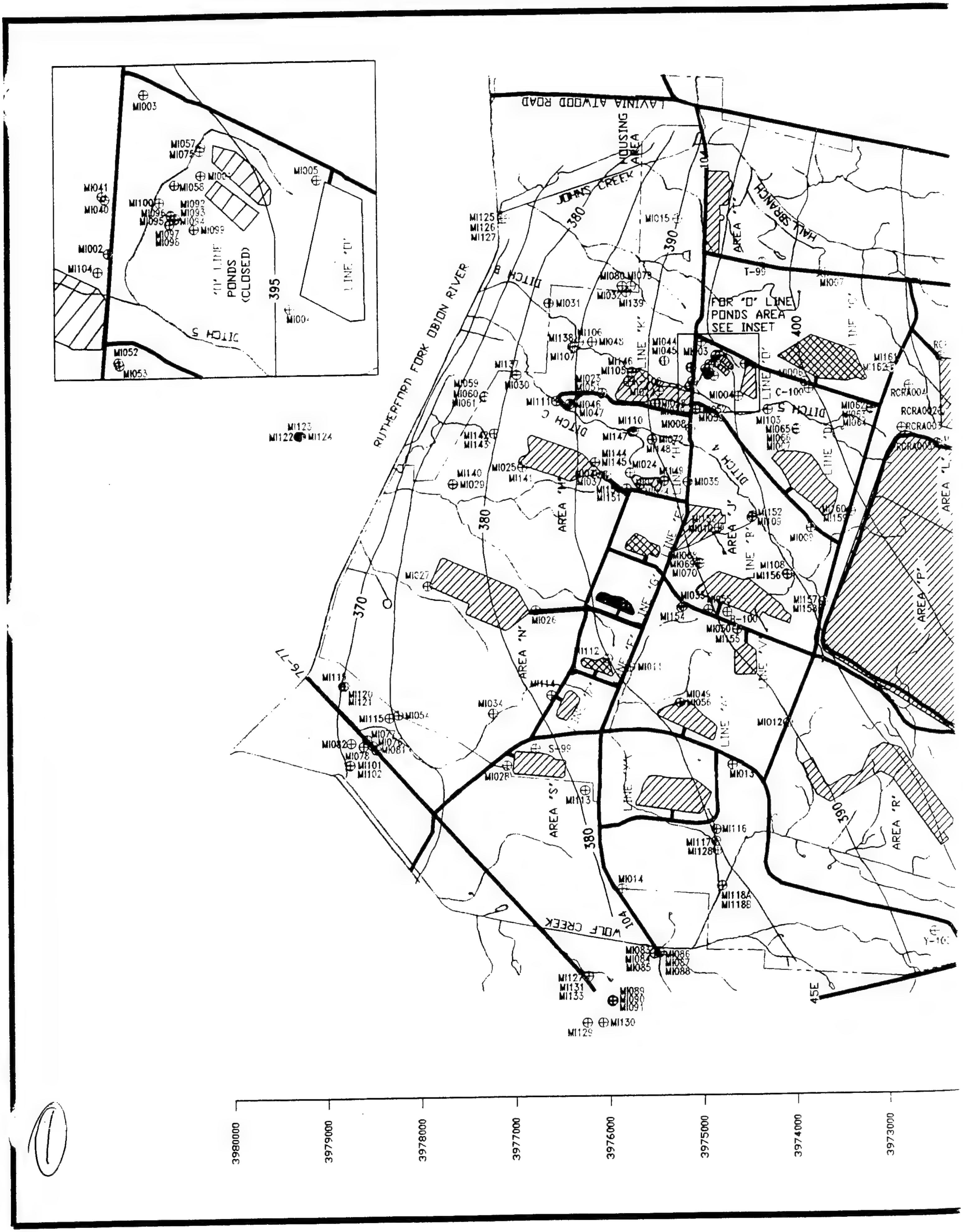
Figure 2-2
East/West Cross Section at MAAP

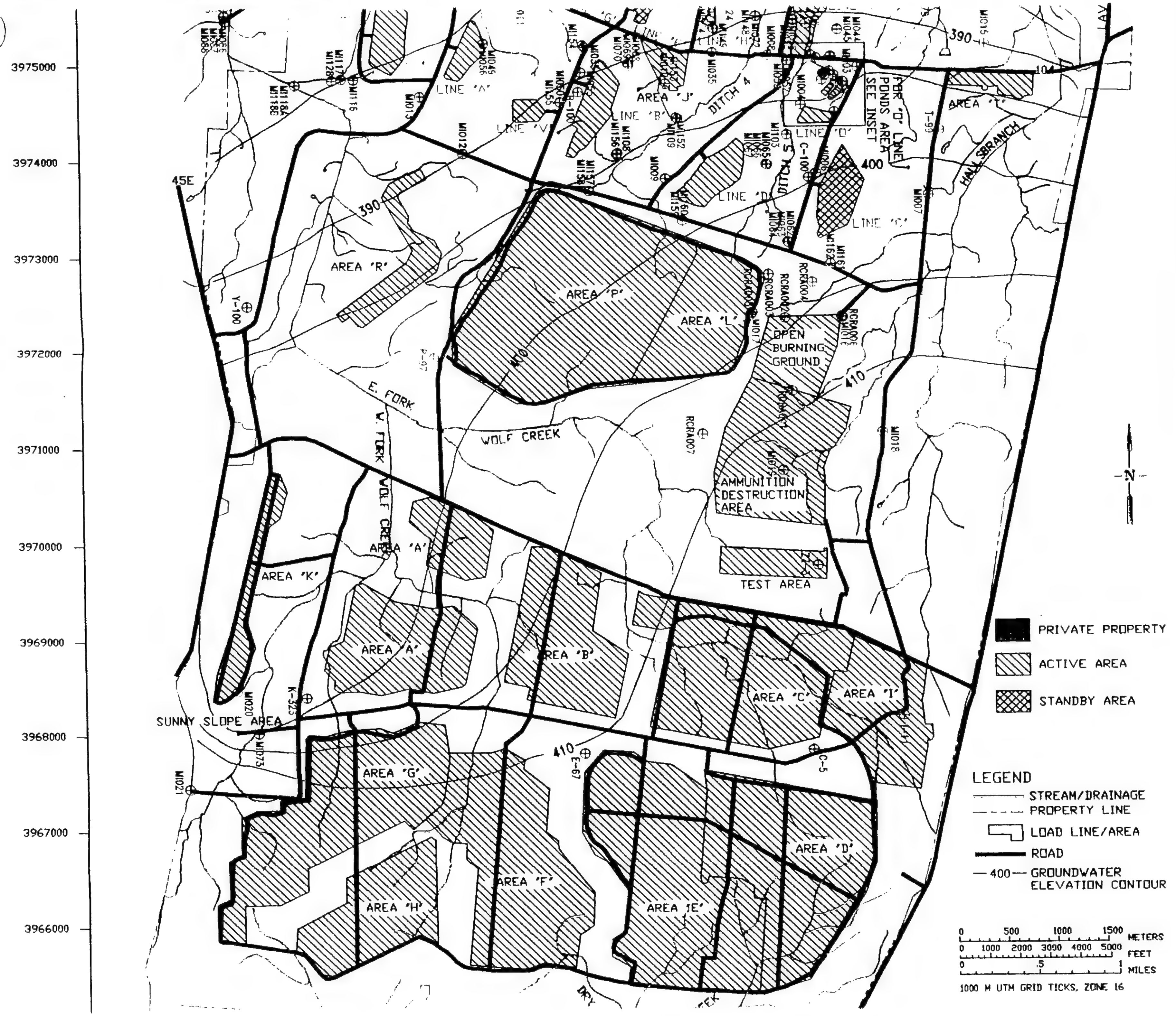


CH - Fat clay, Inorganic clay of high plasticity
CL - Lean clay, sandy clay, silty clay, of low to medium plasticity
ML - Silt and very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
OH - Organic clays of medium to high plasticity, organic silts
OL - Organic silts and organic silty clays of low plasticity
SC - Clayey sand, sand-clay mixtures
SM - Silty-sand, sand-silt mixtures
SP - Sand, poorly graded, gravelly sands

Sandy/Silty/Clay/Loamy Soil
Sandy/Silty Clay
Clay
Sand
Clay Layers 0.5-6 inches thick
Water Table

Figure 2-3
North/South Cross-Section at MAAP


LAVINIA ATWOOD ROAD
HOUSING AREA
JOHNS CREEK
HALL BRANCH
RUTHERFORD FORK OBION RIVER
WOLF CREEK
FOR "D" LINE PONDS AREA SEE INSET
"D" LINE PONDS (CLOSED)
LINE 'D'
DITCH 5
DITCH C
DITCH 4
DITCH B
AREA 'N'
AREA 'S'
AREA 'P'
AREA 'R'
AREA 'J'
LINE 'K'
LINE 'G'
LINE 'B'
C-100
T-99
S-99
76-77
45E
104
370
380
390
395
400
3980000
3979000
3978000
3977000
3976000
3975000
3974000
3973000


LEGEND
PRIVATE PROPERTY
ACTIVE AREA
STANDBY AREA
STREAM/DRAINAGE
PROPERTY LINE
LOAD LINE/AREA
ROAD
400 GROUNDWATER ELEVATION CONTOUR
0 500 1000 1500 METERS
0 1000 2000 3000 4000 5000 FEET
0 .5 1 MILES
1000 M UTM GRID TICKS, ZONE 16
N
3975000
3974000
3973000
3972000
3971000
3970000
3969000
3968000
3967000
3966000
FOR 'O' LINE PONDS AREA SEE INSET
AREA 'P'
AREA 'L'
AREA 'R'
AREA 'A'
AREA 'B'
AREA 'C'
AREA 'D'
AREA 'E'
AREA 'F'
AREA 'G'
AREA 'H'
AREA 'I'
AREA 'J'
AREA 'K'
AREA 'T'
OPEN BURNING GROUND
AMMUNITION DESTRUCTION AREA
TEST AREA
SUNNY SLOPE AREA
E. FORK
W. FORK
WOLF CREEK
HALL BRANCH
DITCH 4
DITCH 5
LINE 'A'
LINE 'B'
LINE 'C'
LINE 'D'
LINE 'V'
45E
390
400
410
RCRA007
RCRA006
RCRA004
RCRA003
MI016
MI017
MI018
MI007
MI009
MI012
MI013
MI116
MI020
MI021
MI073
MI035
K-323
Y-100
C-100
C-5
E-67
T-99
P-97

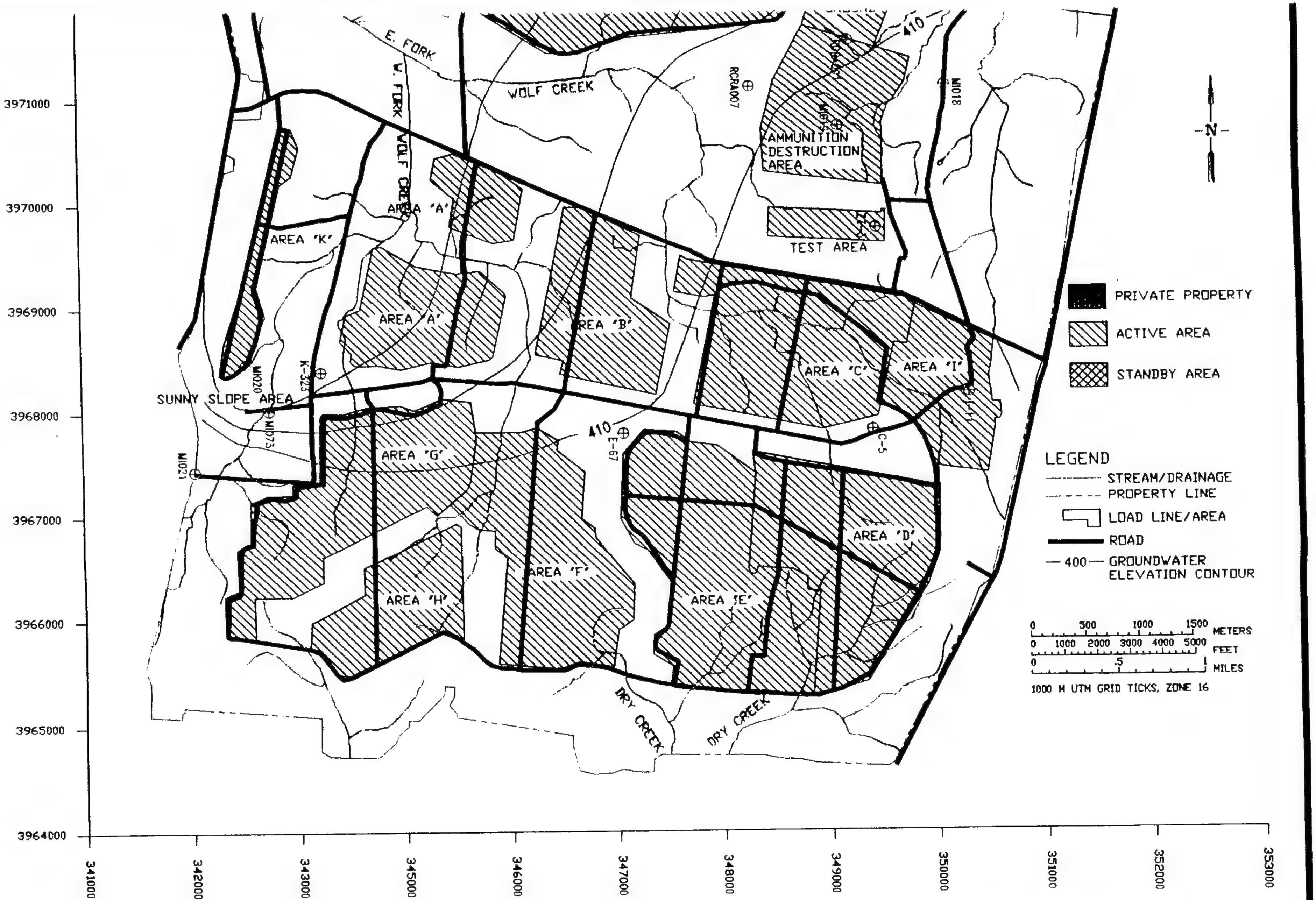


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FIGURE 2-4
SITE MAP

Extensive drilling and borehole logging was conducted at the site as part of the RI (USAEC, 1991a). While drilling in the OBG, localized zones of perched water were encountered. Perched water was not encountered while drilling boreholes in other areas of the site.

2.1.5.1 Estimate of Hydraulic Conductivity. Horizontal hydraulic conductivity of the aquifer beneath MAAP was estimated by several different methods and compared to previous site investigation results and to published values. Table 2-1 provides a summary of these estimates. Results reported by Weston (USAEC, 1983) offer a greater range in conductivity than those reported in the RI (USAEC, 1991a), RI Follow-On (USAEC, 1993a), or the Hydrogeological Investigation Report (USAEC, 1992b). However, solution methods and rationale employed by Weston may have been inappropriate for the data collected. For example, the solution method employed by Weston is based on the assumption that the tested wells fully penetrate the aquifer. In fact, the wells penetrate only 20 to 55 feet of an aquifer which is approximately 250 feet thick at the locations of the tested wells.

Parks and Carmichael (1990) report a conductivity value of 0.0278 ft/min (40 ft/day) for the Claiborne Aquifer determined from a pumping test performed in a municipal supply well in the city of Milan. The Ground Water Manual (U.S. Bureau of Reclamation, 1977) provides a range of hydraulic conductivities between $1x10^{-2}$ to $1x10^{-4}$ ft/min (0.14 to 14 ft/day) for aquifer materials similar to those found at MAAP.

Estimates of hydraulic conductivity were developed from slug test and recovery test data, and grain size analysis of soil samples performed during the RI. Good agreement was obtained between hydraulic conductivity values calculated from these methods. These values also agreed well with the results of the pump test of a production well in Milan, TN, reported by Parks and Carmichael (1990). The RI report estimates that the average value of hydraulic conductivity across the site is 27 ft/day.

As part of the O-Line Ponds investigation, a step-drawdown test, two high-rate pump tests, and a recovery test were conducted for a test extraction well installed north of the O-Line Ponds area (USAEC, 1992a; USAEC, 1992b). The results of these aquifer tests were evaluated to develop estimates of hydraulic conductivity. Both the Theis (1935) solution, modified for partially penetrating wells in unconfined aquifers and the Neuman (1975) solution were used to analyze these data. Recovery test data were analyzed using the Theis (1935) recovery method. Distance-drawdown analysis was also used to estimate the hydraulic conductivity from the drawdown data simultaneously from different wells during the constant-rate tests. The average hydraulic conductivity value from analysis of these aquifer tests is 57 ft/day.

During the RI Follow-On work, ERM developed an estimate of hydraulic conductivity through calibration of a two-dimensional groundwater flow model (USAEC, 1993a). This resulted in an estimate of 97 ft/day with an annual recharge rate of 9.5 in/yr.

2.1.5.2 Groundwater Contours. Water levels were measured in the monitoring wells on December 3, 1990, and again on November 3, 1993. Because the water level contours constructed from the December 1990 data appeared to be in error, all of the monitoring wells within OU3 were resurveyed for elevation in 1993. These corrected well elevation data and water level data were used to generate water level contours. Groundwater contours for the aquifer beneath the site are shown on Figure 2-4. Water levels are highest in the southern half of the site, including elevations of 446 ft-msl in MI021 and 412 ft-msl in MI018. The water table elevation decreases in the northern portion of the site, toward the Rutherford Fork of the Obion River, which is consistent with the decrease in ground surface elevations. In monitoring well MI059, approximately 2,000 feet south of the river, the water table elevation is 379 ft-msl. The elevation of the river directly north of MI059 is approximately 370 ft-msl.

TABLE 2-1
Hydraulic Conductivity Estimates for the Claiborne Aquifer at MAAP and Surrounding Areas

SOURCE	WELL	TEST METHOD	ANALYSIS METHOD	K (FT/DAY)
WESTON STUDIES (1983)				
Weston	K-100	Recovery	Theis, 1935	167.0
Weston	MI030	Recovery	Theis, 1935	15.8
Weston	MI032	Recovery	Theis, 1935	0.4
Weston	MI040	Recovery	Theis, 1935	28.9
Weston	----	Grain Size Analysis Average	Pall & Moshenin, 1980	5688.0
MILAN MUNICIPAL WELL PUMP TEST (1990)				
WRI 88-4182[1]	Milan Municipal Well	Constant Rate Pump Test	Unknown	40.0
ICF REMEDIAL INVESTIGATION (1991)				
ICF	MI057	Recovery	Bouwer-Rice, 1976	34.4
ICF	MI057	Falling Head Slug	Bouwer-Rice, 1976	25.0
ICF	MI057	Rising Head Slug	Bouwer-Rice, 1976	25.5
ICF	MI063	Recovery	Bouwer-Rice, 1976	17.9
ICF	----	Grain Size Analysis Average	Masch & Denny, 1966	32.0
AVERAGE VALUE				27.0
ICF O-LINE PONDS HYDROGEOLOGICAL INVESTIGATION (1992)				
AVERAGE VALUE				57.4
ERM REMEDIAL INVESTIGATION FOLLOW-ON (1993)				
AVERAGE VALUE				97.0

1.Parks, W.S. and J.K. Carmichael, 1990. Personal communication, Jan. 1991.

2.1.5.3 Groundwater Gradients. Groundwater flows in a direction perpendicular to groundwater contours lines, such that groundwater pathlines follow the most direct route from the recharge area to the discharge area. The change in hydraulic head (Δh) over a given distance (ΔL) is the hydraulic gradient ($\Delta h/\Delta L = i$) which drives the flow of water. Representative flow paths for groundwater traveling beneath the site were chosen from starting points south of the OBG to discharge points in surface water bodies or locations beyond the site boundaries. The horizontal gradient at the site has been calculated from the groundwater contour lines, and ranges from 0.0012 to 0.0019 ft/ft. The average gradient for the site is 0.0015 ft/ft.

The general flow directions for groundwater beneath MAAP are perpendicular to the water level contours, as presented in Table 2-4. Groundwater is recharged primarily by precipitation infiltration in highland areas in the southern portion of the site, and discharges to the Rutherford Fork of the Obion River. Groundwater also discharges to the lower reaches of Wolf and Johns Creeks where they flow into the Rutherford Fork. It is evident from the relationships between elevations of the ground surface, the water table, and the stream surface that the aquifer is contributing flow to the surface water bodies. However, given the vertical extent of the aquifer, it is likely that only the shallow portion of the aquifer is discharging to the surface water bodies while deeper portions of the aquifer flow toward regional discharge areas. This partitioning of thick, unconfined aquifers into shallow, intermediate, and deep flow systems is a common occurrence (Toth, 1963). In such settings, local topographic features control flow in the shallowest part of the aquifer while the deeper flow system is influenced by regional controls. The partitioning of flow within the aquifer at MAAP can only be inferred from the available data. However, regional studies have shown that shallow, intermediate, and deep flow systems occur within the Claiborne aquifer (Grubb, 1986).

Well clusters installed at the site allowed for the characterization of vertical groundwater gradients. Water levels measured in 1990 and 1993 show the presence of both upward and downward vertical gradients which range between +0.002 ft/ft to -0.004 ft/ft. The observed vertical gradients vary between well cluster locations, and are apparently unrelated to possible discharge effects imposed by the river. The differences in magnitude of vertical gradients may be a result of local stratification within the aquifer material. Nonetheless, the downward vertical gradients observed in some areas, and particularly near the Rutherford Fork, imply that groundwater beneath the site is moving downward within the Claiborne aquifer and much of the groundwater is not discharging to the Rutherford Fork. The downward flow of groundwater at the site is consistent with the findings of a regional aquifer study (Grubb, 1986). This study found that the western Tennessee area is a regional recharge area for the Claiborne and other aquifers. Groundwater recharging in this area travels downward to the deep flow system of Tertiary aquifers and west to the regional groundwater discharge area in the Mississippi alluvial plain. Shallow and intermediate flow systems within the aquifers are in connection with local surface water bodies such as streams, rivers, and lakes.

2.1.5.4 Groundwater Velocities. The average rate at which groundwater travels across the site can be determined using the following relationship:

$$V = \frac{K(i)}{N_e} \tag{1}$$

where:

V	=	average groundwater flow velocity (ft/day)
K	=	average hydraulic conductivity (ft/day)
i	=	groundwater hydraulic gradient (dimensionless)
N_e	=	effective porosity of the soil (dimensionless)

As previously described, the average flow gradient was calculated based on representative groundwater flow paths for the site, and the average hydraulic conductivity was estimated from aquifer testing methods. Effective porosity refers to the interconnected porosity in the saturated zone that is available for the flow of groundwater. An average value for effective porosity is 20%.

Based on average values of hydraulic parameters for the aquifer at MAAP, an average groundwater flow velocity for the site has been calculated. Using an effective porosity of 20%, an average gradient of 0.0015, and an average hydraulic conductivity of 57 ft/day, the average groundwater flow velocity at the site is 0.4 ft/day. It is important to note that this value for velocity represents an average velocity for the site, and that some variation is expected for various areas of the site.

2.1.5.5 Groundwater Potential and Flow Analysis. Decreasing groundwater potential with depth of screened interval was observed at wells MI059, MI060, and MI061 near the northern boundary at MAAP, and at various other well-cluster locations. Some of the well clusters (e.g., MI052 and MI053, which are located toward the interior of the facility) indicate a slightly increasing potential with depth. The vertical gradients appear to be small (on the order of 0.004 ft/ft) but may be of importance because the horizontal gradients are even smaller (on the order of 0.0015 ft/ft). The vertical gradients depend greatly on the precision of surveying and water level measurements, but there is a reasonable degree of consistency among water level data at various locations.

During the RI, a flow net was constructed using potential data collected from monitoring well clusters. The negative slope of the equipotential lines in the flow net is consistent with the postulation of downward gradients to groundwater flow, as was implied from the decreasing potential with depth at the well-cluster location near the river. The flow net also suggests that the gradient varies across the site, from zero slope or slightly positive slope (tendency for water to move upward) within the interior of the facility to a negative slope (tendency for water to move downward) nearer the river.

Most flow lines near the river would be drawn with a downward angle of about 60 degrees to the horizontal. The data are not sufficient to determine flow lines in the shallow zone, but it appears that only a small fraction (probably less than 10%) of the aquifer discharges into the river.

2.1.6 Site Surface Water Hydrology

Numerous perennial and ephemeral surface water features occur within the installation and flow to the north-northwest as depicted in Figure 2-4. Wolf Creek, the largest interior drainage body, originates at Pine Lake near the southeastern boundary (not depicted in Figure 2-4), and along with three tributaries (Dry Creek, East Fork of Wolf Creek, and West Fork of Wolf Creek) drains the southern and central portions of the installation. Wolf Creek exits along the northwest boundary and empties into the Rutherford Fork of the Obion River. The extreme southern portion of the installation drains south to the Middle Fork of the Forked Deer River (not depicted in Figure 2-4). The northeastern portion of the installation drains to Halls Branch, Johns Creek and then to the Rutherford Fork of the Obion River. The northern portions of MAAP contain several well-developed, ephemeral, natural drainage bodies (including Ditches 4, 5, B, and C shown in Figure 2-4) that join the Rutherford Fork along the northern boundary of the installation. The two parent streams, the Forked Deer River and Obion River, empty into the Mississippi River about 60 miles west of MAAP.

It was observed during the surface water and sediment sampling conducted during the RI that the interior drainage ditches are "losing" ditches; that is, the base flow is zero. Surface water flow occurs only as a result of storm water runoff and industrial wastewater treatment facility (IWWTF) discharge, and surface water recharges groundwater at these times.

During the RI, water level gages were installed at 4 locations to evaluate flow rates through the ditches. Because several surface water gages were installed per ditch system, water balance calculations were used to evaluate the percentage of water that infiltrates the ditch floor and percolates through the vadose zone, as opposed to flowing through the ditch as surface water. In addition, site-specific meteorological data were used to evaluate the rate of evapotranspiration.

When the results of the analysis of evapotranspiration are combined with the results of the stream gage measurements, the following general conclusions may be drawn:

- The ditches are fed primarily by surface runoff during and immediately after storm events. Of the water that reaches the ditch system, approximately 90% of it infiltrates the soil in the ditch floor and 10% flows through the ditch system to the Rutherford Fork.

- Approximately 95% of the precipitation at the site percolates through the soil zone. However, 50% of this water is evapotranspired to the atmosphere. Therefore, approximately 48% of the precipitation at the site percolates through the vadose zone to recharge groundwater.

- The approximate average annual amount of groundwater recharge through precipitation and percolation is 48% of 50 inches per year, or 24 inches per year of annual recharge.

2.2 SITE OPERATIONS AND HISTORY

The initial construction of the installation was completed in January 1942, and the plant has operated continuously since that time. MAAP is a government-owned, contractor-operated (GOCO) military industrial installation under the jurisdiction of the Commanding General, Headquarters, United States Army Armament, Munitions and Chemical Command. Presently, MAAP is operated by Martin Marietta Ordnance Systems, Inc. The current level of employment at MAAP is 1,350 workers.

The general mission of MAAP currently includes:

a. The loading, assembling, and packaging (LAP) of conventional ammunition items as assigned;

b. Operation and maintenance (O&M), as directed, of active facilities in support of current operations;

c. Maintenance and/or layaway, in accordance with regulations for standby facilities, including any machinery and packaged items received from industry, in such condition as will permit rehabilitation and resumption of production within the time limitations prescribed;

d. Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service stocks and V and W Group items of industrial stocks as required or directed; and

e. Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials.

MAAP facilities include thirteen active and inactive ammunition LAP Lines (of which seven are in use at present); one washout/rework line; one experimental line; one central x-ray facility; one test area;

two shop maintenance areas; two magazine storage areas; 12 aboveground, earth-covered igloo magazine storage areas; a demolition and burning ground area; an administrative area; a family housing area; and recreational facilities. In addition, there are medical facilities, fire/ambulance stations, 10 high pressure heating/process steam plants, 16 low-pressure heating plants, and 6 IWWTFs. There are two sewage treatment plants located on the facility: Wolf Creek Ordnance Plant (WCOP) treatment plant in the northern portion of the site, and Milan Ordnance Depot (MOD) sewage treatment plant in the south. A laundry facility for clothing used by on-site personnel while working with explosives/propellants is located in Area J. Located in K-Line is a coal-fired steam plant, a coal pile, a storage pond, and a treatment plant for coal pile runoff.

Approximately 18,600 acres within the MAAP boundary are leased for agricultural use. Approximately 3,984 acres are used as cropland. Cotton, corn, and soybean are the main crops, and smaller amounts of grain sorghum and wheat are also grown. The corn, soybean, grain sorghum, and wheat are grown principally for use as animal feed, but there is no restriction on the use of the crops. In 1991, there were 2,851 head of cattle grazing on the facility. The cattle graze between April and November on about 8,700 acres. In addition, MAAP has more than 6,000 acres of managed timberland.

MAAP has 15 water supply wells that obtain water from the Memphis Sand. Three of the water-supply wells (C-5, S-99, and T-99) are currently in use as potable water sources. Well C-5 supplies potable water to the southern portion of the site while T-99 and S-99, which are high-capacity, recently-installed wells, supply both potable water and production water to the northern portion of the site.

In the past, wastewater from various production activities in the lines was discharged to open ditches that drained from sumps or surface impoundments into both intermittent and perennial streams and rivers. MAAP currently treats all process water from the lines that generate explosives-contaminated wastewater in the six IWWTFs. This wastewater is processed by an activated carbon adsorption system and discharged under the authority of a National Pollution Discharge Elimination System (NPDES) permit.

2.3 CONTAMINATION ASSESSMENT -- NORTHERN INDUSTRIAL AREAS

The northern industrial areas include the following load lines and disposal areas:

- All load lines (which consists of Lines A, B, C, D, E, K, O, X, and Z);
- Closed Landfill; and
- Former Borrow Pit.

These areas were investigated during the RI and results of the investigation are presented in the RI Report (USAEC, 1991a).

For this Focused FS, only the remediation of contaminated soil is considered. The remediation of other environmental media will be evaluated in subsequent studies.

The full investigation of contaminated soil within the northern industrial areas is underway but has not yet been completed. Therefore, the exact extent of areas which contain explosives-contaminated soil have not been identified. This Focused FS is intended to provide a non site-specific procedure for identifying those areas that must be remediated to reduce the residual risk to within the USEPA's target risk range of 10^{-4} to 10^{-6}. The chemical data collected to date from the northern industrial areas is summarized in this section only to the extent that the information is later used in the development of the risk-based soil remediation levels.

2.3.1 Description of the LAP Line Areas

This section summarizes the known information about the operational histories and disposal practices of the LAP Line areas. The source of the information presented in this section is a report describing solid waste management units (SWMUs) performed by A.T. Kearney and Geo/Resource Consultants (USEPA, 1986b); personal communication with Bill Blaylock, Martin Marietta, on April 10, 1991; and a reference manual on military explosives (U.S. Department of the Army, 1984).

2.3.1.1 Line A. LAP Line A has been operated since 1941. Past activities included the renovation of 60-mm mortar rounds, loading fuzes, press loading of 40-mm rounds, and rocket assembly. The explosives handled at this line include Amatol (a mixture of 2,4,6-trinitrotoluene (2,4,6-TNT) and ammonium nitrate), Composition B (a mixture of 2,4,6-TNT and cyclotrimethylenetrinitramine (RDX), and N-methyl-N,2,4,6-tetranitroanaline (tetryl)). Past practices include wastewater discharges to sumps and from the sumps to surface drainage ways. Also included was occasional wash down of the entire assembly line with water. Line wastewater is presently discharged to a IWWTF. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are four sumps at Line A.

2.3.1.2 Line B. Line B has been in operation since 1941. Past activities have included: the renovation of high explosive rocket and artillery rounds; demilitarization of high explosive 37-mm, 40-mm and 75-mm rounds; disassembly of 40-mm shells and 4.5-inch rockets; assembly and loading of various artillery shells; production of 4.5-inch rockets; and segregation and handling of cordite. The explosives loaded at this line include Composition A (a mixture of RDX and a desensitizer, such as beeswax or a synthetic wax) and Composition B. Currently, plastic-bonded explosives are extruded and dried at Line B. These explosives are mixtures of RDX, polystyrene, and Di-N-octyl phthalate. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. Line wastewater is presently discharged to a IWWTF. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are three sumps currently in place and an additional sump which has been closed.

2.3.1.3 Line C. Line C operated from 1941 until the 1970s. Past activities included the use of a melt/pour operation, renovation of rockets, the loading of mortar and rockets, and the disassembly of howitzer shells. Amatol and Composition B were loaded at this line. It is possible that Composition A was also used. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. If the line is reactivated, wastewater will be discharged to the IWWTF. An X-ray facility existed previously at this line. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are seven sumps at Line C.

2.3.1.4 Line D. Line has been in operation since 1941. Past activities included use of a melt/pour operation, the renovation of howitzer and mortar shells, and the loading of howitzer shells. Amatol and Composition B were loaded at this line. It is possible that Composition A was also used. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. If the line is reactivated, wastewater will be discharged to a IWWTF. The melt/pour portion of the line is on standby. Some conventional munitions are being assembled in the D-Line area, and Dupont sheeting, a plastic-bonded explosive, is currently being cut into sheets. A former photographic lab and x-ray facility may have discharged spent solutions to surface drainage ditches. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are four sumps at Line D.

2.3.1.5 Line E. Line E operated from 1941 until the 1970s. Past activities included the assembly of fuzes, booster leads, and the blending and pelletizing of tetryl. Prior to the Vietnam War, the fuzes were made of tetryl. After the Vietnam War, Composition A5 was used, which is a mixture of RDX and barium stearate. The facility was operated as a dry line, although past practices may have included discharges to a sump or drainage ditch. The site is presently on standby status. One sump at Line E was investigated during the RI.

2.3.1.6 Line K. Although Line K was not investigated during the RI, groundwater sampling and analysis of wells downgradient from this area indicated that Line K may be a source of metal contamination. To determine if Line K is a source of groundwater contamination, facility personnel were interviewed to determine what operations had been performed in this area. The information gathered from these interviews is presented in this section.

Line K has been used for both metal parts production and munitions production. Both activities are currently inactive and the line is now being used as a storage area. According to Thomas Allen (personal communication, 1991), a retired MAAP employee who previously supervised the work at K-Line, metal plating operations were performed in Building K-50. These plating operations continued until about 10 or 15 years ago. Both zinc chromate electrolytic plating and cadmium electrolytic plating processes were used, and both of these processes were cyanide-based. The main plating tank had a capacity of 33,000 gallons, so it appears that metal plating was a large-scale operation.

Wastewater from the plating processes was treated to convert hexavalent chromium to trivalent chromium. The pH was adjusted with sulfuric acid and the cyanide was neutralized to reduce the toxicity of the wastewater. The water was then discharged to the nearby drainage ditch. A pond located in K-Line was used as part of the treatment system, and probably provided the volume needed for settling of solids and neutralization. This pond was closed a number of years ago. According to Bill Blaylock of MAAP (personal communication, 1991), the soil was tested for contamination and then disposed of at an unknown location. There are no written records of sampling data.

Sludge from the plating process was generated periodically when the process tanks were cleaned. This sludge was loaded onto rail cars. Mr. Allen does not know where the sludge was taken for disposal, but it is likely that the sludge was disposed of on site. Possibly, this occurred in the OBG/ADA areas where disposal and burial of other types of waste were common.

Prior to 1946, ammonium nitrate was manufactured by facility personnel at K-Line for use in agricultural fertilizers. In 1946, a large explosion occurred which destroyed a building and killed several people. A release of ammonium nitrate occurred at this time. The production of ammonium nitrate was discontinued following the accident.

In addition, an X-ray facility previously existed at Line K.

2.3.1.7 Line O. Line O has been in operation since 1941. Line O is a conventional demilitarization facility constructed to remove explosives from bombs and projectiles by injecting a high pressure stream of hot water and steam into the open cavity of the munitions to melt and wash out the explosives fill. Past practices included wastewater discharges from concrete sumps to the O-Line Ponds. Wastewater is presently piped from steel tanks set in concrete pits to the Line O IWWTF. There are three sumps at Line O.

2.3.1.8 Line X. Line X has been in operation since 1941. Past and present activities include the loading of mortar rounds, rockets, and fuzes; demilitarization of 20-mm and 37-mm munitions; renovation of fuzes; and production of mortar and artillery shells. Explosives loaded at this line include Amatol, Composition A5, Composition B, tetryl, and plastic-bonded explosives. Past practices included wastewater

discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are six sump locations at Line X. Two sumps have been closed.

2.3.1.9 Line Z. Line Z was in operation from 1941 to the late 1970s, and production resumed under a third party in 1993. Past production activities included the loading of fuzes. Both tetryl and Composition A5 have been used at this line. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are two sumps at Line Z.

2.3.2 Closed Sanitary Landfill

MAAP operated a landfill located between Line H and Line K, north of Highway 104, from the late 1960s until 1974. This landfill was reportedly used as a general purpose disposal area for paper, construction material, and miscellaneous items including RDX-contaminated packing material. Disposal procedures included the excavation of trenches 8-10 feet deep, 15 feet wide, and 50-75 feet long. These trenches were then filled with inert material, compacted, then covered with soil. Natural topographic lows were utilized where possible. Trace levels of 2,4,6-TNT and 2,6-dinitrotoluene (2,6-DNT) and a higher level of RDX were detected in the soil during a contamination survey conducted by USAEC in 1982 (USAEC, 1982).

2.3.3 Former Borrow Pit (Construction Debris Pit)

The former borrow pit is located directly south of Line H and immediately north of Highway 104. The pit is a former borrow area used to excavate sand for construction activities. MAAP has allowed the disposal of discarded building materials from base construction and renovation activities to occur in this pit. Currently, the former borrow pit contains ponded water.

2.3.4 Description of Previous Investigations

During the RI, all sumps within each of the load lines were investigated by drilling a borehole on the downgradient side of the sump to a depth of 20 feet. Soil samples were collected at the surface and at each five foot interval. All samples were analyzed for explosives compounds and select metals (cadmium, chromium, mercury, and lead). In addition, approximately 10% of the samples were analyzed for volatile organic compounds (VOCs), semivolatile compounds, explosives, and Target Analyte List (TAL) metals.

In addition, a more in-depth study of Line B was conducted in mid-1994. As part of this study, more than 300 surface soil samples were collected in suspected contaminated areas (outside doors in which washout occurred, near sumps, and near ditches). These surface soil samples were analyzed in the field using immunoassay test kits for 2,4,6-TNT and RDX. Because near real-time results could be obtained using the test kits, sampling proceeded in each suspected contaminated area until contaminant contour lines could be established around each contaminated area, including the non-detect line.

The immunoassay test kit for 2,4,6-TNT actually measures the sum of the concentrations of 2,4,6-TNT, 1,3,5-trinitrobenzene (1,3,5-TNB), 2,4-dinitrotoluene (2,4-DNT), tetryl, and 2-Amino-4,6-Dinitrotoluene (2-A-4,6-DNT). The method detection limit for this test kit is approximately 1 μg/g in soil.

The immunoassay test kit for RDX measures the sum of the concentrations of RDX and cyclotetramethylenetetranitroamine (HMX). The method detection limit for this test kit is also approximately 1 μg/g in soil.

The distribution of contaminants within Line B is most likely representative of the other load lines because at various times, melt-pour and pressing activities have taken place within this line. Line B has operated since 1941, and has been one of the most active lines. Therefore, the general conclusions drawn from data collected at Line B will be used in the overall risk assessment for the northern industrial areas.

2.3.5 Contaminants Detected In Soil Samples

During the RI, approximately 10% of all soil samples were analyzed for target compound list (TCL) VOCs, base/neutral-acid extractable compounds, and TAL metals, as well as the explosives compounds. For all suspected source areas investigated within the northern industrial areas, the chemical data indicate that no organic or inorganic analytes other than explosives compounds have been detected in soil at levels of concern. In addition, other organic compounds have not been detected in soil samples in which explosives compounds are not also present.

Explosives compounds have been detected at maximum levels of approximately 10,000 μg/g (in a surface soil sample collected from Line B). However, very few samples collected at MAAP contain total explosives compounds above 100 μg/g.

As expected from the history of the facility, the major explosives compounds detected in soil samples are 2,4,6-TNT and RDX. These two explosives compounds account for approximately 95% of the total mass of explosives compounds detected in soil. The following patterns have also been noted from the data:

- At certain load lines and sumps, tetryl has been detected in the absence of 2,4,6-TNT and RDX. This has occurred at Line E and specific buildings within Lines A and Z. This is due to the fact that tetryl was loaded into fuzes within these areas.

- The breakdown products and/or manufacturing contaminants of 2,4,6-TNT include 1,3,5-TNB, 1,3-dinitrobenzene (1,3-DNB), nitrobenzene, 2,4-DNT, and 2,6-DNT. These compounds are frequently detected in samples in which 2,4,6-TNT is also detected. In general, these compounds have not been detected at concentrations exceeding 5% of the concentration of 2,4,6-TNT detected in the same sample.

- The manufacturing byproduct of RDX detected at MAAP is HMX (which is also a primary explosive but has not been loaded at MAAP). In general, HMX has not been detected at a concentration exceeding 5% of the concentration of RDX.

2.3.5.1 Distribution of Explosives Compounds with Depth. The means by which soil has become contaminated with explosives compounds at MAAP include the following:

- Washout of buildings. In the past, buildings in which large amounts of explosives compounds have been handled (such as through melt/pour operations) have been cleaned through use of a high-pressure water spray. This water was allowed to run out the doors and onto the ground.

- Use of sumps. Industrial wastewater has been directed to sumps, where the bulk of the explosives compounds would settle out and the water would continue to ditches

(presently, all water is directed into a IWWTF prior to discharge). In cases where the sump leaked or was allowed to overflow during rain events, wastewater entered the environment.

- Use of unlined drainageways for discharge of water. Prior to construction of the IWWTFs in 1981, wastewater was allowed to flow from the sumps to larger drainage ditches through unlined drainageways.

All of the above methods resulted in the application of contaminated wastewater to surface soil and resulting leaching through the vadose zone. From this information, it is apparent that the bulk of the contamination would occur in the near-surface layers and would attenuate with depth. The chemical data collected during the RI is in agreement with this premise. In general, the concentration of total explosives compounds decreases at approximately the rate of 1 order of magnitude for every 5 feet of depth.

2.3.5.2 Estimate of Fraction of Northern Industrial Areas that is Contaminated. The surface soil sampling program conducted at Line B consisted of the collection of more than 300 soil samples from areas that were suspected to have become contaminated. Surface soil samples were collected from areas outside of all buildings in which explosives have been directly handled, around all sumps and drywells, and in the drainageways that run from the sumps to the drainage ditches. As stated previously, MAAP facility personnel believe that the level of contamination at Line B is most likely representative of the level of contamination at other load lines because of the similarity of operations at Line B to those within other load lines.

The soil sampling and analysis was conducted to establish lines of non-detection around each suspected source area to allow estimation of the total area within Line B that is contaminated. The information collected from Line B indicates that the total area within Line B that contains explosives compounds above the method detection limit of approximately 1 $\mu g/g$ is approximately 0.1% of the total area.

2.3.6 Conclusions

The following general conclusions may be drawn from the information presented above:

- The primary explosives compounds detected in soil samples collected from the northern industrial areas of MAAP are 2,4,6-TNT and RDX. With the exception of those areas in which tetryl has been the predominant explosives compound, the other explosives compounds have been detected at approximately 5% of the concentration of these primary explosives compounds, or lower.

- In general, the surface soil contains the highest concentration of explosives compounds as compared to subsurface soil samples collected at the same location. The rate at which the concentration of explosives compounds decreases with depth is approximately 1 order of magnitude in concentration per 5 feet of depth.

- The fraction of the total area of a load line that is contaminated has been estimated to be approximately 0.1%.

3.0 REMEDIAL ACTION OBJECTIVES

The remedial action objectives for soil at the northern industrial areas of MAAP are presented in this section. These objectives are specific to explosives-contaminated soil at the northern industrial areas and have been developed to ensure that attainment of these goals will result in the short- and long-term protection of human health and the environment. The remedial action objectives focus on the exposure pathways of concern, which are identified below. Thus, the contaminants of concern, the potential exposure routes and receptors, and the acceptable contaminant level for each exposure route are addressed in this analysis. Remedial action objectives also consider the following criteria:

- Whether the remediation goals for all carcinogens of concern provide protection within the risk range of $1x10^{-4}$ to $1x10^{-6}$;

- Whether the remediation goals set for all noncarcinogens of concern are sufficiently protective;

- Whether environmental effects are adequately addressed; and

- Whether the exposure analysis adequately addresses each human exposure pathway of concern.

For this Focused FS of soil treatment alternatives, the contaminants of concern are the explosives compounds. There are no chemical-specific applicable or relevant and appropriate requirements (ARARs) for these compounds. Risk assessment has been used to calculate the level at which soil remediation should take place to reduce the residual risk to within the USEPA's target risk range of $1x10^{-4}$ to $1x10^{-6}$. For all remedial options under consideration for soil within the northern industrial areas, the action-specific and location-specific ARARs and to-be-considered (TBC) guidance are presented in this section.

This section is divided into three parts, as follows:

- The rationale behind use of immunoassay test kits or colorimetric (Meizenheimer ion) methods is presented. Use of these methods would allow development of risk-based remediation levels based on the carcinogenicity/toxicity information for the primary explosives compounds 2,4,6-TNT and RDX. Approval of this method would simplify and expedite both the development of remedial action objectives and the sampling needed for delineation of contaminated areas.

- Exposure pathways have been identified and risk-based cleanup levels have been developed for the northern industrial area soil.

- Finally, the location-specific and action-specific ARARs for explosives-contaminated soil in the northern industrial areas are presented and discussed.

3.1 RATIONALE FOR USE OF IMMUNOASSAY TEST KITS OR RAPID COLORIMETRIC (MEIZENHEIMER ION) METHODS FOR INVESTIGATION AND CONFIRMATORY SAMPLING

The purpose of this Focused FS is to develop and present potential methods for the remediation of explosives-contaminated soil in the northern industrial areas. During the RI, approximately 115 soil samples were collected from surface and subsurface immediately downgradient of each of the wastewater sumps in the load lines, and numerous soil samples have been collected from the other suspected source areas in the Northern Industrial Area. In addition, approximately 300 soil samples were collected from Line B during the 1994 investigation of this load line. These data have been used to develop a conceptual model of the distribution of contaminants in soil. Because so much data are available for the purpose of

developing a workable model, there is currently the potential to develop a plan for identifying areas that require remediation that is both efficient and cost-effective.

All of the soil samples collected to date indicate that the major contaminants of concern are the explosives compounds. During the RI of MAAP, surface and subsurface soil samples were collected immediately downgradient of each sump in all of the load lines. All soil samples were analyzed for explosives and select metals (Cd, Cr, Pb, Hg), and approximately 50% of the soil samples were analyzed for volatile organic compounds, semivolatile organic compounds, TAL inorganics, and explosives compounds. As discussed in more detail in Section 3.2.1, the detected inorganic analytes exceeded background levels infrequently and by relatively small margins. Three PAH compounds were detected in one subsurface sample at concentrations less than 0.2 μg/g. The source of these PAH compounds may be exhaust from vehicles, the drill rig, or gasoline-powered generators. Acetone, 1,2-epoxycyclohexene, trichlorofluoromethane, and 2-propanol were detected in approximately 5 samples (out of 115 samples) at levels just above their respective CRLs. Several of these organic compounds are common laboratory or transportation contaminants, and 2-propanol was used in equipment decontamination. Although phthalates were used in several of the load lines, these compounds were not detected in the soil.

In the human health risk assessment for the RI, the risk associated with human exposure to both surface soil and subsurface soil was qualitatively evaluated. The organic compounds (other than the explosives compounds) were detected infrequently and at levels far lower than the concentrations of the explosives compounds. The inorganic analytes exceeded the background levels infrequently and also by a small relative amount. Because the areas near the sumps are either paved or vegetated and workers do not generally enter these areas, the potential risk associated with the contaminants in these areas was evaluated as being too low to warrant quantitative evaluation.

Because the sumps received the majority of the wastewater generated at MAAP, and because the soil samples collected immediately downgradient of the sumps do not contain contaminants at levels above background (for inorganics) or significantly above their respective Certified Reporting Limit (CRL) (for non-explosive organic compounds), soil in the areas remote to the sumps is not expected to contain these contaminants at levels of concern.

The areas of contaminated soil within the load lines are limited to isolated spots centered around the wastewater sumps, outside the doorways of select buildings, and near personnel walkways. The total area of contaminated soil has been estimated to be approximately 0.1% of the total load line area, and this fraction is composed of a number of small areas. Because of the small size of the areas with contaminated soil, only negligible isolated ecological impacts could occur. Also, even if contaminants leach to groundwater, the groundwater does not discharge to surface water. Therefore, potential aquatic impacts also are considered to be negligible.

Based on the above, the explosives compounds are identified as being the contaminants for which remediation of the soil should occur. Because the areas of explosives-contaminated soil have not yet been defined, there is a large amount of sampling and analysis remaining to be performed. To reduce the costs associated with these efforts, use of the immunoassay methods or rapid colorimetric (Meizenheimer ion) methods are proposed. The advantages of using either the immunoassay test kits or the rapid colorimetric methods (Meizenheimer ion) are the following:

- These methods are far less costly than use of the standard High Performance Liquid Chromatography (HPLC) method for explosives compounds analysis, so a much larger number of samples could be taken for the same cost;

- The methods are quick-turnaround, so samplers could quickly adjust to the data (e.g., extend the sampling in the directions in which the levels of explosives compounds are higher than the remediation levels and terminate sampling in directions in which explosives compounds are lower than the remediation levels).

- The quantitation limits of both the immunoassay methods and the colorimetric (Meizenheimer ion) methods are approximately 1 μg/g for both of the primary compounds. Provided that the risk-based remediation levels are higher than these quantitation limits, these methods can be used. The test kits for 2,4,6-TNT-related compounds provides quantitation of the sum of the concentrations of 2,4,6-TNT, 1,3,5-TNB, 1,3-DNB, 2,4-DNT, tetryl, and 2-amino-4,6-DNT. The RDX kit provides quantitation of the sum of the concentrations of RDX and HMX.

The rationale for use of these field screening methods is presented below.

3.1.1 Distribution of Explosives Compounds in Soil

The information presented in Section 2.0 regarding the primary explosives compounds at MAAP (2,4,6-TNT and RDX) and the relative concentrations of the breakdown products and/or manufacturing contaminants indicates that approximately 95% of the total mass of explosives compounds present in soil at MAAP are the primary explosives compounds. The secondary explosives compounds, if they are present at all in soil, have been detected at levels of approximately 5% of the concentration of 2,4,6-TNT and RDX.

The secondary explosives compounds associated with 2,4,6-TNT are 1,3,5-TNB, 2,4-DNT, 2,6-DNT, nitrobenzene, and 1,3-DNB. The secondary explosives compound associated with RDX is HMX.

3.1.2 Toxicity of Explosives Compounds

The primary explosives compounds (2,4,6-TNT and RDX) are both noncarcinogens and Class C carcinogens. With the exception of 2,4-DNT and 2,6-DNT, the mixture of which is a probable carcinogen, the secondary explosives compounds are noncarcinogens. The Reference Doses (RfD) and Cancer Slope Factors (CSF) for the explosives compounds are listed in Table 3-1.

The RfD and CSF values in Table 3-1 indicate the following:

- 2,4,6-TNT and RDX have both an RfD and CSF, so both carcinogenic and noncarcinogenic effects can be estimated for these compounds.

- The secondary explosives compounds associated with 2,4,6-TNT have a wide range in RfDs and CSFs, with some displaying more severe toxic/carcinogenic effects and some displaying less toxic/carcinogenic effects.

- HMX is not a carcinogen. Also, its noncarcinogenic effects are less than those of RDX.

Because the primary explosives compounds account for approximately 95% of the total mass of explosives compounds in soil at MAAP, use of the toxic/carcinogenic data for 2,4,6-TNT and RDX for the following groupings of compounds would provide reasonably accurate risk estimates:

- The sum of 2,4,6-TNT, 1,3,5-TNB, 1,3-DNB, 2,4-DNT, and tetryl; and

- The sum of RDX and HMX.

TABLE 3-1
Oral Toxicity Values for Explosives Compounds

Chemical	Chronic Reference Dose (mg/kg-day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	EPA Weight of Evidence Classification (c)	Slope Factor Source
1,3-Dinitrobenzene	$1x10^{-4}$	3,000	Spleen/Weight	IRIS	–	–	–
Dinitrotoluene (2,4 and 2,6 isomers)	$2x10^{-3}$ (2,4) $1x10^{-3}$ (2,6)	100 (2,4) 3,000 (2,6)	CNS (2,4) CNS/Blood/Kidney (2,6)	IRIS HEAST	$6.8x10^{-1}$	B2	HEAST
HMX	$5x10^{-2}$	1,000	Liver	HEAST	–	D	IRIS
Nitrobenzene	$5x10^{-4}$	10,000	Kidney/Liver	IRIS	–	D	IRIS
RDX	$3x10^{-3}$	100	Prostate	IRIS	$1x10^{-1}$	C	IRIS
Tetryl	$1x10^{-2}$	10,000	Liver/Kidney/Spleen	HEAST	–	–	–
1,3,5-Trinitrobenzene	$5x10^{-5}$	10,000	Spleen	IRIS	–	–	–
2,4,6-Trinitrotoluene	$5x10^{-4}$	1,000	Liver	IRIS	$3x10^{-2}$	C	IRIS

(a) Safety factors are the products of uncertainty factors and modifying factors. Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- a 10-fold factor to account for variation in sensitivity among members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = Not classified as to human carcinogenicity.

CNS = Central Nervous System
IRIS = Integrated Risk Information Systems
HEAST = Health Effects Assessment Summary Tables
– = No information available

As a check on the applicability of the 2,4,6-TNT and RDX RfDs and CSFs to remediation of the MAAP Northern Industrial soil, the following additional calculations were performed:

- First, it was assumed that 95% of the sum of the 2,4,6-TNT-related compounds is due to 2,4,6-TNT and 5% is composed of the remaining 2,4,6-TNT-related compounds. Further, if it is assumed that 2.5% of the total concentration of 2,4,6-TNT-related compounds is 2,4-DNT, then the resulting increase in risk can be estimated. The carcinogenic risk would be increased by approximately 5%.

- If 2.5% of the total concentration of 2,4,6-TNT-related compounds is due to the presence of 1,3,5-TNB, then the hazard index would exceed one. However, the target organ for 1,3,5-TNB (spleen) differs from that of 2,4,6-TNT (liver), and the uncertainty factor for 1,3,5-TNB is much larger than that used for 2,4,6-TNT because of the limited data used in deriving the RfD.

- Because the RfD for HMX is larger than the RfD for RDX, the assumption that any fraction of RDX-related compounds is due to the presence of HMX reduces the hazard index for the sum of RDX-related compounds.

Therefore, use of either the immunoassay test kits or the colorimetric (Meizenheimer ion) rapid screening methods would be appropriate for use in investigation and confirmatory sampling of soil. Use of these methods would greatly reduce the analytical costs associated with the project and would yield data of sufficient representativeness to be used in delineating those areas of soil contamination which should be remediated.

The calculation of risk-based soil cleanup levels presented below therefore focuses on the risks and adverse effects of RDX and 2,4,6-TNT. Tetryl will also be evaluated separately because it has been used extensively at the fuze load lines.

3.2 DEVELOPMENT OF RISK-BASED SOIL CLEANUP LEVELS

This evaluation has been prepared to identify potential exposure pathways and to derive clean-up levels for soil in the northern industrial areas of MAAP. These soil clean-up levels are designed to be protective of exposures via potentially complete current and future pathways. The soil clean-up levels for each pathway evaluated will be compared and the most conservative level will be proposed for use as the remediation level. The methodology used in deriving clean-up levels for soil followed relevant guidance and standards developed by the United States Environmental Protection Agency (USEPA 1986a, 1989a,b, 1991, and 1992a,b).

The soil clean-up levels were derived only for areas of probable contamination around historically active areas of the load lines. Only human receptors were considered in this evaluation, as ecological impacts associated with soil in the northern industrial areas are not considered to be significant. As described in Section 3.2.2.4, only negligible isolated ecological impacts associated with contaminated soil would be expected to occur in the northern industrial portions of MAAP. As a result, clean-up levels were developed assuming that humans would be the principal receptors to chemicals of potential concern.

The remainder of this section is organized as follows:

Section 3.2.1 <u>Identification of Chemicals of Potential Concern</u>. The principal chemicals of potential concern in soil are identified and the basis of their selection is discussed. Chemicals of potential concern are selected for further evaluation based on a review of historical waste disposal activities and on an evaluation of previous sampling data.

Section 3.2.2 Exposure Assessment. The potential pathways by which human receptors may be exposed to chemicals of potential concern in soil and other media that may be affected by the contaminants in soil are discussed; exposure pathways and potential receptors are then selected for evaluation. Assumptions are made for the magnitude, frequency, and duration of exposure for selected receptors in the northern industrial areas at MAAP. An ecological exposure assessment also is presented, in which potential ecological receptors and the suitability of the northern industrial areas as ecological habitat are discussed.

Section 3.2.3 Toxicity Assessment. The potential toxicity of chemicals to humans and the range of toxic effects for each chemical of potential concern are described and the chemical-specific health effects criteria to be used in the quantitative assessment are presented.

Section 3.2.4 Derivation of Remediation Levels. Clean-up levels in soil are derived for all receptors of concern by combining toxicity criteria and relevant exposure parameters.

Section 3.2.5 Uncertainty Section. This section summarizes the uncertainties inherent in using risk assessment methodologies to derive clean-up levels for soil.

Section 3.2.6 Conclusions. The conclusions of the report are presented.

3.2.1 Selection of Chemicals of Potential Concern

This section discusses the identification and selection of chemicals of potential concern in the northern industrial areas of MAAP. This information, which was presented earlier in Section 3.1, is based on a knowledge of historical waste disposal activities and on the results of soil sampling that was conducted in the areas of concern. The previous sampling results indicate that the areas of contaminated soil within the load lines of the industrial areas are limited to isolated spots located around the wastewater sumps, outside the doorways of select buildings, and near personnel walkways. The total area of contaminated soil has been estimated to be approximately 0.1% of the total load line area, and this fraction is composed of a number of small areas.

All of the soil sampling performed to date indicates that the major contaminants of concern are explosives compounds. All soil samples have been analyzed for explosives compounds and select metals (Cd, Cr, Pb, and Hg), and approximately 50% of the soil samples were analyzed for volatile organic compounds, semivolatiles, and TAL inorganics. An examination of the sampling data indicates that the non-explosive organic compounds were detected infrequently and at levels far lower than the concentrations of the explosives compounds. The detected inorganic analytes exceeded background levels infrequently and by relatively small margins. Of the 96 soil samples from the sumps within the load lines, cadmium, cobalt, mercury, nickel, silver, vanadium, and zinc exceeded two times the background concentration only once each (the background concentrations used in this analysis are those in the RI Report, December, 1991). These exceedances are widely distributed in depth and among the load lines, and appear to be unrelated to manufacturing or disposal activities.

Where the chemical concentrations in the load lines exceeded respective background concentrations, the maximum load line concentrations were compared to health-based levels to determine whether exposures to the chemical could result in adverse impacts, and therefore should be carried through this remediation goal evaluation. The health-based levels used for this comparison were risk-based concentrations (RBCs) developed by USEPA Region III, which are screening levels to be used in the initial stages of a risk assessment when selecting chemicals for quantitative evaluation. The soil RBCs are designed to be protective of human health, and are based on conservative exposure assumptions for

industrial workers. Back-calculated from a risk of one-in-one million ($1x10^{-6}$) for carcinogenic chemicals and a hazard index of 1.0 for noncarcinogenic chemicals, these are concentrations below which adverse health effects would not be expected to occur as a result of exposures to the medium (i.e., chemicals present in soil below these concentrations are not carried though the quantitative evaluation, because risks associated with these chemicals would not be of concern with respect to potential health).

Six samples exceed the level of two times the background concentration for arsenic. The highest concentration detected in soil, 14 μg/g, was higher than its industrial RBC of 1.6 μg/g. The 1.6 μg/g RBC for arsenic is based on worker exposures to soil, and conservatively assumes that a worker incidentally ingests soil 250 days per year for 25 years. Because such frequent contact with soils is not likely, and because arsenic exceeded the RBC at only 6 locations, arsenic at the load lines is not considered to be of concern. In addition, the toxicity criteria for arsenic is considered to be overly conservative and associated with great uncertainty.[1] As a result, arsenic's RBC (i.e., a health-protective value) would likely be greater than 1.6 μg/g if more appropriate toxicity criteria were developed. The only potential source of arsenic at the site is the use of arsenicals as herbicides, thus any arsenic that is present above background levels is likely due to the past use of herbicides. For manganese, 6 samples exceed the level of 2 times the background concentration; the highest concentration detected in soil is 2,800 μg/g, which is less than the RBC for worker exposure of 5,100 μg/g. From the site manufacturing history, there is no reason to suspect that use or disposal of manganese occurred at the site.

Based on this information, explosives compounds have been identified as the principal chemicals of potential concern in these industrial areas of MAAP. Specifically, 2,4,6-TNT, 1,3,5-TNB, 1,3-DNB, 2,4-DNT, 2,6-DNT, tetryl, RDX, HMX, and nitrobenzene have been detected in soil and groundwater. However, based on an understanding of the sampling data and the transport of the explosives compounds to subsurface soil and groundwater, it appears that 2,4,6-TNT and RDX were detected most consistently in these media and in greatest concentrations. Tetryl has also been detected at the fuze lines. These three explosives are considered to be the predominant explosives compounds in the northern industrial areas, and concentrations of other explosives compounds are typically found to be below levels of concern with respect to human health. Accordingly, soil clean-up levels will be determined for these three explosives compounds.

During the excavation of the soil, some of samples will be analyzed for the entire suite of Target Compound List (TCL), Target Analyte List (TAL) chemicals, and explosives compounds, both to confirm the results of the colorimetric analyses and also to determine whether significant levels of other chemicals may be present. If other chemicals of potential concern are detected in the confirmatory samples, the methodology described in this RA to develop remediation goals is not considered appropriate to use, and additional analyses may need to be conducted to determine the appropriate clean-up levels of the chemicals of concern.

In summary, based on a historical knowledge about waste disposal in the load line areas and on previous sampling in the northern industrial areas of MAAP, 2,4,6-TNT, RDX, and tetryl were considered to be the principal compounds of potential concern for which clean-up goals were derived. The following

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[1]The carcinogenicity of ingested inorganic arsenic is a matter of controversy and there are several sources of uncertainty regarding arsenic's carcinogenic potency, including the fact that the dose-response curve may be less than linear causing the slope factor to overestimate risk at lower doses and that arsenic may be an essential human nutrient (USEPA 1988). Also, a 1988 memorandum from the Administrator of the USEPA cited in IRIS (1994) regarding arsenic stated that "risk managers must recognize and consider the qualities and uncertainties of risk estimates. The uncertainties associated with ingested inorganic arsenic are such that estimates could be modified downwards as much as an order of magnitude, relative to risk estimates associated with most other carcinogens."

section, Exposure Assessment, discusses the potential pathways through which receptors could be exposed to these three explosives compounds.

3.2.2 Exposure Assessment

This section discusses the potential for human health and ecological exposures at the northern industrial areas of MAAP. Human receptors in these areas and their potential routes of exposure are first presented. This is followed by a discussion on the potential routes of exposure for ecological receptors in these northern industrial areas.

3.2.2.1 Human Exposure Assessment. In this section, the potential pathways by which individuals may be exposed to the explosives compounds of concern in soil are identified. Potential pathways associated with other media that may be affected by the contamination in the soil (i.e., groundwater) are also identified. This information will be the basis for calculating clean-up levels for the receptors who may be exposed to contaminants of potential concern. Although clean-up levels for all selected exposure pathways will be calculated, the most conservative (i.e., health protective) clean-up levels in soil will be selected for remediation purposes.

An exposure pathway, which describes the course a chemical takes from the source to the exposed individual, is defined by four elements:

- A source and mechanism of chemical release to the environment;
- An environmental transport medium (e.g., groundwater, soil) for the released chemical;
- A point of potential contact with the contaminated medium (referred to as the exposure point); and
- An exposure route (e.g., ingestion) at the contact point.

An exposure pathway is considered complete only if all four elements are present, and only complete exposure pathways are quantitatively evaluated.

When conducting an exposure assessment, USEPA (1989a, 1991) guidance requires that plausible exposures under both current and future land-use scenarios be evaluated. The current land-use scenario assumes conditions as they currently exist, while the future land-use scenario evaluates conditions that may be associated with probable changes in site use, assuming no remedial action occurs.

3.2.2.2 Potential Exposure Pathways Under Current Land-Use Conditions. The potential exposure pathways through which human receptors could be exposed to contamination resulting from past activities along the load lines and sumps are discussed below for current land-use conditions. Table 3-2 summarizes this analysis, indicating the exposure media, source and release mechanisms, potential receptors, and exposure routes. This table also indicates whether the pathway is potentially complete, and identifies those pathways for which clean-up levels will be calculated.

Surface Soil. As noted above, the principal areas of explosives contamination in soil are located in the vicinity of buildings where the explosives compounds were loaded and packaged, and around sumps. Thus, under current land-use scenarios, workers who come into contact with these soil may be exposed to the explosives contamination. Although routine worker activities are likely to be very limited to the buildings in which they work, it is nevertheless possible that workers who work inside the buildings

TABLE 3-2
Potential Human Exposure Pathways Under Current Land-Use Conditions at the MAAP Load Lines

Exposure Medium	Source/Mechanism of Release	Receptor	Exposure Route	Pathway Potentially Complete? Basis	Method of Evaluation
Surface soil	Contaminated wastewater from washing down insides of buildings where explosives were used.	On-site industrial worker	Dermal contact and/or incidental ingestion of soil.	Yes. Industrial workers could come into contact with contaminated soils.	Remediation goals calculated. Industrial workers could come into contact with contaminated soils.
		On-site lawn maintenance worker	Dermal contact and/or incidental ingestion of soil.	Yes. Lawn maintenance workers could come into contact with contaminated soils.	None. Surface soil in contaminated areas around buildings would not be as frequently contacted by lawn maintenance workers as by industrial workers.
		Trespassers	Dermal contact and/or incidental ingestion of soil.	Yes. Trespassers could come into contact with contaminated soils.	None. Trespassers exposures would be less frequent than exposures to industrial workers at MAAP.
Subsurface soil	Contaminated runoff from washing down buildings and from disposal of liquid wastes into sumps.	On-site excavation worker	Dermal contact and/or incidental ingestion of soil.	No. No ground-intrusive activities are occurring under current operations at the MAAP load lines.	None. Pathway is not complete.
Groundwater	Leaching of chemicals from surface soil and sumps, primarily around buildings.	On-site worker	Ingestion and/or dermal contact.	No. Groundwater not used as a drinking water source or for any other purpose by individuals at MAAP.	None. Pathway is not complete.
Air	Dust generation from contaminated soils or volatilization of VOCs in soils or shallow groundwater.	On-site worker	Inhalation of wind-generated dusts or volatilized VOCs.	No. VOCs are not chemicals of concern and area is well vegetated.	None. Pathway is not complete.

as well as maintenance workers who investigate potential environmental releases could be exposed to surface soil on a routine basis. Workers who mow and conduct lawn maintenance work around the buildings also could be exposed to surface soil; however, their exposures would be primarily in grassy areas farther away from the buildings, and on a less frequent basis. Based on the industrial worker being a potential receptor in the load line area, clean-up levels based on a worker's contact with soil (i.e., incidental ingestion and dermal absorption of chemicals in soil) were calculated.

Trespassers who enter the site may also be exposed to contaminants in surface soil. All of the load lines and other industrial areas are fenced, limiting potential access by trespassers. However, even if trespassers were to come on site, their exposure would be much less frequent than a worker's exposures (both in the exposure frequency [number of days per year exposed] as well as the exposure duration [number of years exposed]). Therefore, exposures and associated clean-up levels for surface soil by trespassers were not considered in this assessment because clean-up levels calculated for workers were assumed to also be protective of trespassers.

Subsurface Soil. Subsurface soil is likely to be contacted only if excavation activities are performed. Excavation or other intrusive activities are not expected in the northern industrial areas under current land-use conditions; therefore, exposures to subsurface soil are unlikely to occur under current land-use conditions, and clean-up levels associated with an excavation scenario were not calculated.

Groundwater. Contaminants in soil may leach into the groundwater below the load lines and receptors who drink or dermally contact this groundwater may be exposed. Groundwater from the contaminated portions of the northern industrial areas of MAAP is not currently used as a drinking water source or for any other purpose by either on- or off-site individuals. Rather, personnel working at MAAP obtain their drinking water from production wells in uncontaminated areas (Areas S and T). As a result, there are no complete pathways associated with exposure to chemicals of potential concern in groundwater, and soil clean-up levels for the protection of groundwater were not calculated for any groundwater receptors under current land-use conditions.

Air. Inhalation exposures to chemicals of concern could result from the transport of chemicals on dust particles by wind entrainment and from the volatilization of chemicals from surface soil or groundwater. Migration of chemicals by wind entrainment of dust particles is not considered to be a significant transport process in most areas of contamination in the northern industrial portion of MAAP, as the areas are typically vegetated and/or paved. Because VOCs are not chemicals of potential concern in soil or groundwater, inhalation of volatilized chemicals is not a complete pathway in the areas of concern. The explosives compounds of concern, 2,4,6-TNT, RDX, and tetryl have very low vapor pressures of 5.5×10^{-6}, 4.03×10^{-9}, and 5.69×10^{-9} torr at 25° C, respectively, so volatilization will not occur at levels of concern.

Summary of Pathways Selected for Evaluation Under Current Land-Use Conditions. In summary, based on current activities in the northern industrial areas at MAAP, clean-up levels were calculated to be protective of incidental ingestion and dermal absorption of chemicals in surface soil by an industrial worker.

3.2.2.3 Potential Exposure Pathways Under Future Land-Use Conditions. Due to the industrial nature of the northern load line areas at MAAP, the industrial areas that were considered for evaluation in this assessment will most likely remain in their current industrial status rather than become developed for other uses in the future. This is consistent with the current usage of the load lines that have been excessed to date; these areas are now used for the manufacturing of furniture and ammunition containers. Nevertheless, for the purposes of this evaluation, it was conservatively assumed that a hypothetical resident actually could reside at the load lines at some point in the future. For the purposes of this

evaluation, it was assumed that no remedial action would occur at the site prior to future industrial activities at the site.

Table 3-3 summarizes the potential exposure pathway analysis under future land-use conditions, indicating the exposure media, source and release mechanisms, potential receptors, exposure route, and whether or not the pathway is potentially complete for chemicals at or originating from the industrial areas of concern. The only exposure pathways that were evaluated under future land-use conditions are those that are likely to change from the current land-use conditions.

Surface Soil. Although the current industrial nature of the northern load lines will most likely remain the same in the future, for the purposes of this RA, it was assumed that residents could build a house and live in the load lines area. Therefore, clean-up levels based on a future resident's potential exposures to surface soil (i.e., via incidental ingestion and dermal absorption of chemicals in soil) were calculated.

Subsurface Soil. Subsurface soil would be accessible for contact by workers performing excavation activities. Although no excavation activities are currently performed at the site, ground intrusive activities, such as excavation of soil for industrial development, for example, could occur. Excavation workers could be exposed to chemicals in subsurface soil via incidental ingestion and/or dermal absorption. It is unlikely that future residents who could live at the load lines would have contact with subsurface soils, thus clean-up levels associated with their potential exposures to subsurface soils were not calculated. In summary, only clean-up levels associated with an excavation worker's exposures to subsurface soils were calculated.

Groundwater. As discussed for the current land use scenario, contaminants in soil may leach into groundwater below the load lines. Groundwater at MAAP is potable, so exposure to chemicals in groundwater could occur as a result of installation and use of a wells by future residents who could live at the load lines. Future residents could become exposed to the explosives compounds in the groundwater primarily via the ingestion pathway. As a result, soil clean-up levels designed to be protective of groundwater ingestion by future residents were developed. Ingestion of groundwater was assumed to be the predominant exposure pathway for future residents, as explosives compounds do not volatilize (thus inhalation while showering would not be of concern). Furthermore, exposures and associated risks via ingestion of RDX, 2,4,6-TNT, and tetryl in groundwater would be much greater than exposures and associated risks via dermal absorption of these chemicals while bathing. As a result, groundwater ingestion was the only pathway considered when developing soil clean-up levels protective of groundwater.

In addition to potential future residential uses of groundwater, wells could be installed at the load lines to be used for industrial and domestic (e.g., cleaning and consumption) purposes. As a result, workers could be exposed to explosives compounds in groundwater via ingestion. However, because workers' exposures would most likely be much lower than those of residents, clean-up levels only for residents were calculated, since they also would be protective of potential future workers consuming groundwater.

Air. As it is unlikely that future conditions at the site would result in greater generation of dusts at the site, the air pathway was not re-evaluated under future land-use conditions.

Summary of Pathways Selected for Evaluation Under Potential Future Land-Use Conditions. As noted above, the evaluation of potential future exposure scenarios focused on exposure scenarios that may occur in the future, under different land-use conditions. Clean-up levels for soil were calculated to be protective of the following potential exposure pathways that could occur under future land-use conditions:

TABLE 3-3
Potential Human Exposure Pathways Under Future Land-Use Conditions at the MAAP Load Lines

Exposure Medium	Source/Mechanism of Release	Receptor	Exposure Route	Pathway Potentially Complete? Basis	Method of Evaluation
Surface soil	Contaminated wastewater from washing down insides of buildings where explosives were used.	On-site industrial worker	Dermal contact and/or incidental ingestion of soil.	Yes. Surface soil is available for contact if workers are on-site.	None. Pathway is evaluated under current land-use conditions.
		On-site residents	Dermal contact and/or incidental ingestion of soil.	Yes. Surface soil is available for contact if residents live on-site.	Remediation goals calculated. Future residents could come into contact with contaminated soils.
Subsurface soil	Contaminated runoff from washing down buildings and from disposal of liquid wastes in sumps.	On-site excavation worker	Dermal contact and/or incidental ingestion of soil.	Yes. Subsurface soil could be contacted if excavation activities were to occur.	Remediation goals calculated, as pathway is complete under future land-use conditions.
		On-site residents	Dermal contact and/or incidental ingestion of soil.	Yes. Subsurface soil could be contacted if residents were to dig below the surface soil.	None. It is not very likely that residents will dig this deep. Further, exposures would be less than via exposures to surface soil.
Groundwater	Leaching of chemicals from surface soil and sumps.	On-site worker	Ingestion, inhalation, and dermal contact.	Yes. Groundwater is of potable quality and could be used in the future.	None. Industrial exposures to chemicals in groundwater would be less than residential exposures.
		On-site residents	Ingestion, inhalation, and dermal contact.	Yes. Groundwater is of potable quality and could be used in the future.	Remediation goals calculated for soil, to be protective of groundwater ingestion. Inhalation and dermal contact were not considered to be significant pathways of exposure. See text.
Air	Dust generation from contaminated soils or volatilization of VOCs in soil or shallow groundwater.	On-site worker	Inhalation of wind-generated dusts or volatilized VOCs.	No. VOCs are not chemicals of concern, and area is well vegetated.	None. Pathway is not complete.
		On-site resident	Inhalation of wind-generated dusts or volatilized VOCs.	No. VOCs are not chemicals of concern, and area is well vegetated.	None. Pathway is not complete.

- Incidental ingestion and dermal absorption of chemicals in surface soils by future residents;

- Incidental ingestion and dermal absorption of chemicals in excavated subsurface soil by an excavation worker; and

- Ingestion of groundwater by a future resident.

3.2.2.4 Ecological Exposure Assessment. It is highly unlikely ecological resources would be adversely affected by explosives in the northern industrial areas of MAAP. As previously indicated, the principal areas of explosive contamination in soil are immediately adjacent to the buildings where explosives were loaded and packaged, and around the sumps. The habitat in these areas is comprised predominantly of mowed grasses and bare soil areas. Because of the highly disturbed nature and poor quality of the habitat around the buildings and sumps, very few ecological receptors are expected to occur and potentially be exposed to chemicals in these areas. Instead, the majority of wildlife on the northern area of MAAP are expected to occur in the less disturbed habitats surrounding the industrialized areas. More importantly, however, the total area of contaminated soil is estimated to be approximately 0.1% of the total load line area, and even if ecological resources were to be exposed to explosives in these areas, it is highly unlikely that adverse effects would occur to ecological receptor populations/communities.

3.2.3 Toxicity Assessment

The general methodology for the classification of health effects and the development of health effects criteria is described in Section 3.2.3.1 to provide the analytical framework for the characterization of human health impacts. In Section 3.2.3.2, the health effects criteria that are used to derive estimates of risk are presented, and the toxicity of the chemicals of potential concern is briefly discussed. These toxicity values are combined with dose information for the evaluated pathways to develop clean-up levels for relevant media of concern.

The methodology used for classifying health effects from exposure to chemicals is recommended by USEPA (1986a, 1989a, 1993, 1994a,b). This health effects analysis considers chronic (long-term) exposures. The chronic toxicity criteria were obtained from USEPA's most recent Integrated Risk Information System (IRIS) and USEPA's Health Effects Assessment Summary Tables (HEAST). These are USEPA's recommended sources for chronic toxicity criteria, and the most recent dose-response values available are used in the assessment.

3.2.3.1 Health Effects Classification and Criteria Development. For RA purposes, individual chemicals are separated into two categories of chemical toxicity depending on whether they exhibit principally carcinogenic (cancer-causing) or noncarcinogenic effects. This distinction relates to the currently held scientific opinion that the mechanism of action for each category of health effects is different. For the purpose of assessing risks associated with potential carcinogens, USEPA has adopted the scientific policy position that a small number of molecular events can evoke changes in a single cell, or a small number of cells, which can then lead to tumor formation. This assumption can be described as a no-threshold model, because there is essentially no level of exposure (i.e., a threshold) to a carcinogen that will not result in some finite possibility of causing cancer. Another assumption stemming from USEPA's science policy is that the dose-response curve is linear at low doses. In reality, this curve can take many shapes depending on the exact biological mechanisms of action of a chemical.

In the case of chemicals exhibiting noncarcinogenic effects, however, it is believed that organisms have repair and detoxification capabilities that must be exceeded (threshold) by some dose or agent before the health effect is manifested. For example, an organ can have a large number of cells

performing the same or similar functions that must be significantly depleted before the effect on the organ is realized. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable risk of adverse effects.

3.2.3.2 Health Effects Criteria for Potential Carcinogens. For chemicals exhibiting potential carcinogenic effects, USEPA's Carcinogen Assessment Group has estimated the excess lifetime cancer risks associated with various levels of exposure to potential human carcinogens by developing Cancer Slope Factors (CSFs) and Unit Risks (URs). CSFs describe the potential increase in an individual's risk of developing cancer over a 70-year lifetime per unit of intake or dose, where the unit of exposure is expressed in terms of reciprocal dose (mg chemical/kg body weight-day)$^{-1}$. URs are expressed as either a reciprocal air concentration ($\mu g/m^3$)$^{-1}$, or as a drinking water concentration ($\mu g/L$)$^{-1}$. The derivation of UR values for either inhalation or drinking water exposures requires the use of specific (conservative) assumptions about exposure conditions and receptor behavior. Because regulatory efforts are generally geared to protect public health, including the most sensitive members of the population, the CSFs and URs are derived using very conservative assumptions.

CSFs and URs are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies usually are conducted using relatively high doses to detect possible adverse effects in small numbers of experimental animals. Because humans are expected to be exposed to doses lower than those used in the animal studies, the data are adjusted by using mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response curve. After the data are fit to the dose-response model, the 95% upper confidence limit (95% UCL) of the slope of the low-dose portion of the dose–response curve is subjected to various adjustments, and an interspecies scaling factor is applied to derive the CSF for humans. This CSF value represents an upper 95% confidence limit on the probability of a response per unit of daily intake of a chemical over a lifetime (i.e., there is only a 5% chance that the probability of a response could be greater than the estimated value on the basis of the experimental data and model used).

When the CSF is multiplied by the lifetime average daily dose (LADD) of a potential carcinogen (in mg/kg-day), or when the UR is multiplied by the inhalation exposure concentration of the potential carcinogen (in $\mu g/m^3$), the product is a lifetime individual cancer risk (or maximum probability of contracting, not dying from, cancer) associated with exposure at that dose. The risk estimate for a given level of set exposure assumptions is unlikely to be underestimated but it may very well be overestimated, due to the inherent conservativeness in the CSFs (i.e., they are upper-bound estimates). An individual risk level of one in one million (1×10^{-6}), for example, represents an upper-bound probability of 0.0001% that an individual will develop cancer over his or her lifetime as a result of lifetime exposure to a potential carcinogen. By comparison, the average American's background risk of developing cancer is approximately one in three (i.e., 33% [American Cancer Society, 1992]), or 330,000 times higher than a one in one million risk level.

USEPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. The weight-of-evidence classification is an attempt to determine the likelihood that an agent is a human carcinogen; the classification thus affects the uncertainty associated with potential health risks, although it does not impact numerical potency (i.e., it does not affect the CSF or UR values). Three major factors are considered in characterizing the overall weight-of-evidence for carcinogenicity: (1) the quality of the evidence from human studies; (2) the quality of evidence from animal studies, which are combined into a characterization of the overall weight-of-evidence for human carcinogenicity; and (3) other supportive information that is assessed to determine whether the overall weight-of-evidence should be modified. USEPA's final classification of the overall evidence has five categories:

- Group A chemicals (human carcinogens) are agents for which there is sufficient evidence from epidemiological studies to support a causal association between exposure to the agents and cancer.

- Group B chemicals (probable human carcinogens) are agents for which there is limited evidence from epidemiological studies of carcinogenicity to humans (B1) or for which, in the absence of adequate data on humans, there is sufficient evidence of carcinogenicity from animal studies (B2).

- Group C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals, and an absence of data for humans.

- Group D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available.

- Group E chemicals (evidence of non-carcinogenicity in humans) are agents for which there is no evidence of carcinogenicity in adequate human or animal studies.

The cancer risks developed in this report are all accompanied by this weight-of-evidence classification. The reader should keep in mind that regardless of potency, there are important qualitative differences between risk estimates for chemicals that have been demonstrated to be human carcinogens and those chemicals for which the evidence is limited.

3.2.3.3 Health Effects Criteria for Noncarcinogens. Health effects criteria for chemicals exhibiting noncarcinogenic effects are generally developed using verified reference doses (RfDs) and reference concentrations (RfCs). These are developed by USEPA's RfD/RfC Work Group and are available on IRIS (USEPA 1994a) or through USEPA's HEAST (USEPA 1994b).

RfDs are expressed in units of dose (mg/kg-day), while RfCs are expressed in units of concentration (mg/m^3). RfDs and RfCs are usually derived either from human studies involving work-place exposures or from animal studies. Chronic RfDs or RfCs are estimates (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to a human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during long-term exposures (seven years or longer). RfDs/RfCs are used as a reference point for gauging the potential effects of exposures. Usually, exposures (as chemical intakes, doses, or inhalation exposure concentrations) that are less than the RfD or RfC are not likely to be associated with adverse health effects. As the frequency and/or magnitude or the exposures exceeding the RfD/RfC increase, the probability of adverse effects in a human population increases.

The RfDs/RfCs are derived using uncertainty factors that reflect scientific judgement regarding the various types of data used to estimate the RfD/RfC. RfDs/RfCs are estimated from no-observable-adverse-effect-levels (NOAELs) or lowest-observable-adverse-effect-levels (LOAELs) in human or animal studies. LOAELs and NOAELs are obtained from chronic toxicity studies in laboratory animals, and are the lowest level at which a toxic effect occurs, and the level at which no toxic effects are manifested, respectively. To derive RfDs/RfCs, NOAELs or LOAELs are divided by one or more uncertainty factors, as appropriate. Uncertainty factors, generally 10-fold factors, are intended to account for:

(1) The variation in sensitivity among members of the human population;

(2) The uncertainty in extrapolating animal data to the case of humans;

(3) The uncertainty in extrapolating from data obtained in a study that is less-than-lifetime exposure;

(4) The uncertainty in using lowest-observable-adverse-effect level (LOAEL) data rather than no-observable-adverse-effect level (NOAEL) data; and

(5) The inability of any single study to adequately address all possible adverse outcomes in humans.

When taken together, these uncertainty factors may confer an extra margin of safety up to a factor of 10,000 below a LOAEL. In some cases, modifying factors are also applied to RfDs/RfCs to take into account other uncertainties in the toxicity database and reflect the professional judgement of those reviewing the database. The net result of incorporating these uncertainty factors is that RfDs/RfCs always bias risk estimates in the direction of overestimation of the likelihood of adverse noncarcinogenic effects.

3.2.3.4 Health Effects Criteria for Individual Chemicals of Potential Concern. Chronic oral health effects criteria (RfDs and CSFs) for the chemicals of potential concern to be quantitatively evaluated were presented earlier in Table 3-1. The toxicological properties of the chemicals of potential concern and the toxicological basis of the health effects criteria are also presented in Table 3-1. Because no pathways involving inhalation are evaluated, no chronic inhalation toxicity criteria are presented. In accordance with USEPA (1989a) guidance, chronic RfDs were used to develop remediation goals for all pathways where exposures would be greater than seven years. Although USEPA (1989a) guidance considers exposure periods of less than seven years to be subchronic, chronic RfDs were used instead of subchronic RfDs when developing remediation goals for the excavation scenario, where the exposure duration would be only one year. The chronic RfDs are more conservative and add a measure of protection to the subchronically exposed receptors.

The evaluation of dermal exposures, in contrast to ingestion and inhalation exposures, is complicated by the fact that toxicity criteria for this route of exposure are unavailable. As a result, oral toxicity criteria (CSFs or RfDs) were used to assess dermal exposure estimates. In order to have a meaningful comparison between the dermal dose estimates, which represent internal (or absorbed) doses, and toxicity criteria, which typically represent potential (or administered) doses, toxicity criteria should be modified to represent absorbed doses. (In cases where the toxicity criteria are based on internal doses, this modification is not required.) The method for modifying toxicity criteria involves determination of an absolute oral absorption factor for each chemical and use of this value to increase the chemical's oral cancer slope factor or decrease the chemical's oral RfD (USEPA 1989a). Cancer slope factors and RfDs adjusted in this manner are then more appropriate to assess absorbed dose-response, rather than administered dose-response. The absolute oral absorption factors that are applied should reflect the specific conditions under which the toxicological study was conducted (e.g., method of administration such as gavage, water or diet, and vehicle of administration such as solvent or solution). An absolute oral absorption fraction from the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile documents (ATSDR 1992) is available for 2,4,6-TNT (i.e., 60%). Because no absolute oral absorption factors were available for RDX and tetryl, a default absolute oral absorption factor of 50% (0.50 for semi-volatile organics) was used for both explosives, in accordance with USEPA Region IV guidance. The adjusted RfDs are calculated by multiplying the RfD by the absolute oral absorption factor and the adjusted CSFs are calculated by dividing the CSF by the absolute oral absorption factor. The adjusted toxicity criteria used to evaluate dermal exposures are presented on Table 3-4.

3.2.4 Derivation of Remediation Goals

Based on the rationale provided in Section 3.2.2, remediation goals were based solely on protection of human receptors in the northern industrial areas of MAAP; ecological receptors were not

TABLE 3-4
Adjusted Oral Toxicity Values for Explosives Compounds of Concern

Chemical	Absolute Oral Absorption Factor	Chronic Reference Dose (mg/kg-day)	Adjusted Reference Dose (mg/kg-day)	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Adjusted Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$
RDX	0.50 (a)	3×10^{-3}	1.5×10^{-3}	1.1×10^{-1}	2.2×10^{-1}
Tetryl	0.50 (a)	1×10^{-2}	5.0×10^{-3}	--	--
2,4,6-TNT	0.60 (b)	5×10^{-4}	3×10^{-4}	3×10^{-2}	5×10^{-2}

(a) Default value for semi-volatile organics, based on USEPA Region IV guidance.
(b) Value obtained from ATSDR (1992) for 2,4,6-trinitrotoluene.

-- No cancer slope factor exists for tetryl.

assumed to have significant exposures in these areas. Remediation goals for soil were derived by incorporating conservatively-derived USEPA default exposure parameters and USEPA toxicity criteria into the equations presented below. As discussed earlier in Section 3.2.3.1, the evaluation of carcinogenic chemicals and noncarcinogenic chemicals is conducted separately, as the mechanisms of action for these two groups of chemicals are different (i.e., the no-threshold effect for carcinogens and a threshold effect for noncarcinogens). The USEPA has established a typical acceptable risk range (to evaluate carcinogens) for remedial planning at Superfund sites. This target risk range of one in ten thousand ($1x10^{-4}$) to one in one million ($1x10^{-6}$) is the chance of developing (not dying of) cancer as a result of exposure to the carcinogen under specified exposure conditions. In this evaluation, risk-based remediation goals were developed using a target risk level of $1x10^{-5}$, the median of the USEPA acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$. This target risk level is considered appropriate due to the anticipated limited industrial uses of the load lines in the future.

Potential adverse impacts associated with oral exposures to noncarcinogens are presented as the hazard quotient. Hazard quotients that are less than 1.0 should be viewed as indicating that adverse effects would not be associated with the exposures being evaluated, while hazard quotients exceeding 1.0 indicate the potential for occurrence of adverse effects. As a result, for noncarcinogenic chemicals, risk-based remediation goals were calculated to correspond to a target hazard quotient of 1.0. 2,4,6-TNT and RDX exhibit both carcinogenic and noncarcinogenic effects, so two risk-based remediation goals for these chemicals are presented for each pathway evaluated. Tetryl exhibits only noncarcinogenic effects, thus only one risk-based remediation goal for tetryl is presented for each pathway.

3.2.4.1 Soil Remediation Goals for Contact with Soil.

Soil Ingestion. Remediation goals associated with ingestion exposures to explosives compounds in soil for industrial and excavation workers and for hypothetical future residents were calculated using the following equation and the exposure parameters summarized in Table 3-5 and discussed below. The equation used to calculate the remediation goals for ingestion of soil for carcinogenic chemicals is:

$$RG_c = \frac{1x10^{-5} * BW * AT_c * 365\ days/year}{EF * ED * IR * CSF * CF}$$

where

RG_c	=	Remediation goal for carcinogens (mg/kg),
$1x10^{-5}$	=	Target risk value (unitless),
BW	=	Body weight (kg),
AT_c	=	Averaging time (70 years for carcinogens),
EF	=	Exposure frequency (days/year),
ED	=	Exposure duration (years),
IR	=	Ingestion rate (mg/day),
CSF	=	Cancer slope factor $(mg/kg\text{-}day)^{-1}$, and
CF	=	Conversion factor ($kg/10^6$ mg).

The equation used to calculate the remediation goals for ingestion of soil for noncarcinogenic chemicals is:

$$RG_{nc} = \frac{1.0 * BW * AT_{nc} * 365\ days/year * RfD}{EF * ED * IR * CF}$$

TABLE 3-5
Exposure Parameters for Incidental Ingestion of and Dermal Contact with Chemicals in Surface and Subsurface Soil
Current and Future Land-Use Conditions

Parameters	Current Industrial	Future Excavation	Future Resident
Age Period	Adult	Adult	0-30
Exposure Frequency [EF] (days/year or events/year)[a]	250	40	350
Exposure Duration [ED] (years)[b]	25	1	30
Ingestion Exposure Parameters:			
Soil Ingestion Rate [IR_s] (mg/day)[c]	50	480	120
Direct Contact Exposure Parameters:			
Skin Surface Area Available for Contact [SA] (cm^2)[d]	3,500	3,500	3,800
Soil-to-Skin Adherence Factor [AF] (mg/cm^2-event)[e]	1.0	1.0	1.0
Dermal Absorption Factor [Ab] (dimensionless)[f]	0.01	0.01	0.01
Body Weight [BW] (kg)[g]	70	70	48
Averaging Time [AT] (years)[h]			
Carcinogenic Effects	70	70	70
Noncarcinogenic Effects	25	1	30

[a]For industrial workers, frequency shown is a USEPA (1991a) default value, assuming work is performed 5 days/week for 50 weeks/year. For excavation workers, value shown is based on working 5 days/week for 2 months during one year. The residential exposure frequency is the USEPA (1989a, 1991) default value, assuming a resident is at home throughout the year, except for two weeks of vacation away from the home.
[b]For industrial workers, duration shown is a USEPA (1991a) default value for time spent working at one location. For excavation workers, duration shown assumes that construction will be completed within one year. The residential exposure duration is based on the national upper-bound time at one residence (USEPA 1989a, 1991).
[c]For industrial workers, ingestion rate shown is a USEPA (1989a, 1991a) default value for ingestion of soil by persons in the workplace. The ingestion rate for excavation workers is a USEPA (1991a) default value for ingestion of soil during short-term outdoor construction/maintenance type of activities. The residential soil ingestion rate is a weighted-average ingestion rate, assuming 1-6 year olds ingest soil at a rate of 200 mg/day, while older residents ingest soil at a rate of 100 mg/day (USEPA 1989a, 1991).
[d]Value derived from data presented in USEPA (1985), averaging across gender. It is assumed that workers' hands and arms are uncovered and exposed to soil, while the residents' hands, ½ the arms, and ½ the legs are uncovered an exposed to soil.
[e]Value shown is recommended by USEPA (1992b).
[f]Value shown is the recommended default value for organic chemicals (USEPA Region IV 1992c).
[g]The body weight shown for workers is a USEPA (1989a, 1991a) default value for an adult. The body weight shown for residents is a time-weighted average for 0-30 year olds, based on data provided in USEPA (1989b).
[h]The averaging time for carcinogenic effects is based on USEPA (1991a, 1989a) standard assumption for lifetime; for noncarcinogenic effects, the averaging time is equal to the exposure duration.

where

RG_{nc}	=	Remediation goal for noncarcinogens (mg/kg),
1.0	=	Target hazard quotient (unitless),
BW	=	Body weight (kg),
AT_{nc}	=	Averaging time (equal to exposure duration for noncarcinogens),
RfD	=	Reference dose (mg/kg-day),
EF	=	Exposure frequency (days/year),
ED	=	Exposure duration (years),
IR	=	Ingestion rate (mg/day), and
CF	=	Conversion factor (kg/10^6 mg).

The exposure parameters used to develop the remediation goals associated with worker exposures are default worker exposure parameters provided by USEPA. However, some of the USEPA default exposure parameters differ slightly for the industrial workers and the excavation workers. For both worker scenarios, the average body weight value of 70 kg for an adult was used, and is based on data provided by the USEPA (1989a, 1991). The averaging time for carcinogens was equal to a lifetime of 70 years, while the averaging time for noncarcinogens was equal to the exposure duration of each scenario (25 years for the industrial worker and one year for the excavation worker).

Industrial workers were assumed to be exposed to surface soil 250 days/year, a standard USEPA (1991) default assumption assuming a 5-day work week for 50 weeks/year. Duration of exposure for workers was assumed to be 25 years, a USEPA (1991) upper bound default value for time spent working in one location. The daily soil ingestion rate for the industrial worker was assumed to be 50 mg/day, a standard USEPA (1989a, 1991) default value for exposure to persons in the workplace. It was conservatively assumed that all soil ingested during the workday by industrial workers would originate from the load lines.

The exposure frequency and duration for an excavation scenario is much shorter in comparison to the industrial worker exposure scenario described above. Most excavations are one time occurrences that occur over a fairly short duration. For the purposes of this assessment, it was assumed that workers would be involved in the excavation project for a duration of two months. The exposure frequency was assumed to be five days per week over this eight-week period (resulting in a total exposure frequency of 40 days), while the exposure duration was one year. Excavations may result in more intimate contact with loose soil and therefore an increased soil ingestion rate. The ingestion rate used in this assessment was 480 mg/day, as suggested by USEPA (1991) for short-term construction/maintenance types of outdoor activities. It was conservatively assumed that all soil ingested during the workday by remediation workers would originate from the load lines.

A time-weighted average body weight of 48 kg for 0-30 year old residents was calculated based on data in USEPA (1989b). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used for the AT value to evaluate potential carcinogenic effects. To calculate potential noncarcinogenic exposures for residents, AT was equal to the duration of exposure (i.e., 30 years). Future residents (0-30 years of age) were assumed to be exposed to surface soil 350 days/year, a standard default value recommended by USEPA (1989a, 1991). The duration of exposure for the future resident was based on the age period of concern (30 years). The weighted-average soil ingestion rate of 120 mg/day is based on USEPA (1989a, 1991), assuming an ingestion rate of 200 mg/day for 1-6 year olds and an ingestion rate of 100 mg/day for older persons. It was conservatively assumed that all soil ingested during the day by residents would originate from the load lines.

The risk-based remediation goals developed for industrial and excavation worker soil ingestion exposures are presented in Table 3-6, while the risk-based remediation goals for future residential soil

TABLE 3-6
Soil Risk-Based Remediation Goals for Excavation and Industrial Workers[a]

Chemical	Industrial Worker Soil Contact[b]			Excavation Worker Soil Contact[b]		
	Carcinogenic	Noncarcinogenic	Overall Remediation Goal[c]	Carcinogenic	Noncarcinogenic	Overall Remediation Goal[c]
RDX	520 (I)	6,100 (I)	220	8,500 (I)	4,000 (I)	3,500
	380 (D)	4,400 (D)		58,000 (D)	27,000 (D)	
Tetryl	-- (I)	20,000 (I)	9,400	-- (I)	13,000 (I)	12,000
	-- (D)	18,000 (D)		-- (D)	91,000 (D)	
2,4,6-TNT	1,900 (I)	1,000 (I)	470	31,000 (I)	670 (I)	600
	1,700 (D)	900 (D)		255,000 (D)	5,500 (D)	

(a) Remediation goals are in concentrations of mg/kg, and were rounded to two significant figures. The remediation goal for carcinogens was based on a target risk of $1x10^{-5}$, while the remediation goal for noncarcinogens was based on a hazard quotient of 1.0.
(b) Remediation goals for soil contact were calculated for both ingestion and dermal pathways.
I=remediation goal calculated for ingestion of chemicals in soil
D=remediation goal calculated for dermal absorption of chemicals in soil.
(c) The overall remediation goals are based on a worker simultaneously being exposed to chemicals via the ingestion and dermal pathways.

TABLE 3-7
Soil Risk-Based Remediation Goals for Residents[a]

Chemical	Residential Soil Contact[b]				
	Carcinogenic		Noncarcinogenic		Overall Remediation Goal[c]
RDX	90	(I)	1,300	(I)	55
	140	(D)	2,000	(D)	
Tetryl	--	(I)	4,200	(I)	2,600
	--	(D)	6,600	(D)	
2,4,6-TNT	320	(I)	200	(I)	130
	620	(D)	400	(D)	

(a) Remediation goals are in concentrations of mg/kg, and were rounded to two significant figures. The remediation goal for carcinogens was based on a target risk of 1×10^{-5}, while the remediation goal for noncarcinogens was based on a hazard quotient of 1.0.
(b) Remediation goals for soil contact were calculated for both ingestion and dermal pathways.
I=remediation goal calculated for ingestion of chemicals in soil
D=remediation goal calculated for dermal absorption of chemicals in soil.
(c) The overall remediation goals are based on a resident simultaneously being exposed to chemicals via the soil ingestion and dermal pathways.

ingestion exposures are presented in Table 3-7. The USEPA (1994a,b) toxicity criteria used in these calculations were presented earlier in Table 3-1. Since both carcinogenic and noncarcinogenic toxicity criteria exist for both 2,4,6-TNT and RDX, two remediation goals are presented for these chemicals, while only one remediation goal is presented for tetryl, which exhibits only noncarcinogenic effects.

Dermal Absorption of Chemicals in Soil. Remediation goals associated with dermal exposures to explosives compounds in soil for industrial and excavation workers and for residents were calculated using the following equation and the exposure parameters summarized in Table 3-5 and discussed below. The equation used to calculate the remediation goals for dermal exposures to explosives compounds in soil for carcinogenic chemicals is:

$$RG_c = \frac{1x10^{-5} * BW * AT_c * 365\ days/year}{EF * ED * SA * AF * Ab * CSF_{adj} * CF}$$

where

RG_c	=	Remediation goal for carcinogens (mg/kg),
$1x10^{-5}$	=	Target risk value (unitless),
BW	=	Body weight (kg),
AT_c	=	Averaging time (70 years for carcinogens),
EF	=	Exposure frequency (days/year),
ED	=	Exposure duration (years),
SA	=	Skin surface area available for contact (cm^2/day),
AF	=	Soil-to-skin adherence factor (mg/cm^2),
Ab	=	Dermal absorption factor (unitless),
CSF_{adj}	=	Cancer slope factor $(mg/kg\text{-}day)^{-1}$ (adjusted for the dermal pathway), and
CF	=	Conversion factor (kg/10^6 mg).

The equation used to calculate the remediation goals for dermal exposures to explosives compounds in soil for noncarcinogenic chemicals is:

$$RG_{nc} = \frac{1.0 * BW * AT_{nc} * 365\ days/year * RfD_{adj}}{EF * ED * SA * AF * Ab * CF}$$

where

RG_{nc}	=	Remediation goal for noncarcinogens (mg/kg),
1.0	=	Target hazard quotient (unitless),
BW	=	Body weight (kg),
AT_{nc}	=	Averaging time (equal to exposure duration for noncarcinogens),
RfD_{adj}	=	Reference dose (mg/kg-day) (adjusted for the dermal pathway),
EF	=	Exposure frequency (days/year),
ED	=	Exposure duration (years),
SA	=	Skin surface area available for contact (cm^2/day),
AF	=	Soil-to-skin adherence factor (mg/cm^2),
Ab	=	Dermal absorption factor (unitless), and
CF	=	Conversion factor (kg/10^6 mg).

The parameters describing exposure frequency (EF), duration of exposure (ED), body weight (BW), and lifetime for calculating worker dermal exposures are identical to those used for estimating ingestion of soil by industrial or excavation workers. As discussed earlier, for noncarcinogenic effects,

the AT is equal to the exposure duration when evaluating noncarcinogenic effects, while for carcinogenic effects, AT is equal to a lifetime of 70 years.

Additional parameter values that were used to calculate dermal absorption exposures are the amount of chemical absorption, the amount of soil adhering to the skin, and the area of exposed skin. The values used to estimate the surface area of exposed skin of both the industrial and excavation workers were calculated using data from USEPA (1985), and were based on assumptions regarding parts of the body that would be available for contact with soil. For this pathway, it was assumed that the skin surface area (SA) available for contact for workers was 3,500 cm^2 per day, which assumes the hands and arms are exposed. The USEPA (1992b) recommended default soil-to-skin adherence factor (AF), which describes the degree to which the soil adheres to the skin, of 1.0 mg/cm^2 was used.

The parameters describing exposure frequency, duration of exposure, body weight, and lifetime for calculating residential dermal exposures are identical to those used for estimating ingestion of soil by hypothetical future residents. As discussed earlier, the AT is equal to the exposure duration (i.e,. 30 years) when evaluating noncarcinogenic effects for residents, while for carcinogenic effects, AT is equal to a lifetime of 70 years.

The values used to estimate the surface area of exposed skin of the residents were calculated using data from USEPA (1985), and were based on assumptions regarding parts of the body that would be available for contact with soil. For this pathway, it was assumed that the skin surface area (SA) available for contact for 0-30 year old residents was 3,800 cm^2 per day, which assumes the hands, one-half the legs, and one-half the arms are uncovered and exposed. The USEPA (1992b) recommended default soil-to-skin adherence factor (AF), which describes the degree to which the soil adheres to the skin, of 1.0 mg/cm^2 was used.

The amount of chemical absorbed through the skin into the body from contacting surface soil is also needed to estimate dermal exposures. The results of an intensive investigation into the amount of a chemical that may be absorbed through the skin under conditions normally encountered in the environment (and assumed to occur for this assessment) are, however, almost completely lacking. For a chemical to be absorbed by the skin from contacted soil, it must be released from the soil matrix, and pass through the stratum corneum, the epidermis, and the dermis, before it can be absorbed into the systemic circulation (Klaassen et al. 1986). In contrast, chemicals absorbed by the lung or gastrointestinal tract may pass through only two cell layers (Klaassen et al. 1986). The amount of exposure due to dermal absorption is evaluated by estimating the fraction of absorption from contacted soil that may occur for chemicals. A number of factors can affect the dermal absorption of a compound, including the concentration in the applied dose, the site of exposure, inter-individual variability, and the vehicle by which the chemical is delivered to the skin (e.g., in a solvent or soil matrix). Because of the paucity of experimental data on dermal absorption from soil, not all of these parameters can be taken into account in estimating dermal absorption factors. Following USEPA Region IV guidance, dermal absorption factor to be used to determine the risks associated with dermal exposures to organic chemicals in soil is 0.01 (i.e., 1%).

The risk-based remediation goals developed for industrial and excavation worker dermal exposures are presented in Table 3-6, while risk-based remediation goals developed for residential dermal exposures are presented in Table 3-7. The USEPA (1994a,b) oral toxicity criteria adjusted for dermal exposures used in these calculations were presented earlier in Table 3-4. As noted for the soil ingestion exposures, since RDX and 2,4,6-TNT have both carcinogenic and noncarcinogenic toxicity criteria, two remediation goals are presented; only one remedial goal is provided for tetryl, as it is only a noncarcinogen.

Overall Soil Remediation Goals for Ingestion and Dermal Absorption of Chemicals. In order to determine remediation goals that would be protective of both ingestion and dermal exposures simultaneously (as both exposures would likely be occurring at the same time when workers or residents contact soil), the remediation goals for the individual pathways were combined, as follows:

$$\frac{1}{RG_{soil}} = \frac{1}{RG_{ing}} + \frac{1}{RG_{derm}}$$

where

RG_{soil}	=	Overall soil remediation goal assuming exposures via both the dermal and ingestion pathways;
RG_{ing}	=	Ingestion remediation goal; and
RG_{derm}	=	Dermal absorption remediation goal.

Along with the individual ingestion and dermal remediation goals, overall soil remediation goals are presented in Table 3-6 for both types of workers, while overall remediation goals for residential exposures are presented in Table 3-7. It should be noted that the overall remediation goals are lower than the individual goals, since the overall goals are developed to be protective of simultaneous dermal and ingestion exposures.

3.2.4.2 Soil Remediation Levels for the Protection of Future Groundwater Users. Potable water at MAAP is currently obtained from production wells located in uncontaminated areas. As noted earlier, groundwater in the northern industrial areas is not being used, thus no complete exposure pathways currently exist. Under future land-use conditions, it is possible that groundwater in the northern industrial areas could be used as drinking water by residents. As a result, this section presents the methodology for developing acceptable soil clean-up levels, based on migration of contamination to groundwater and subsequent ingestion by future residents.

In order to estimate a soil remediation level that is protective of potential drinking water exposures, the concentration in groundwater that is protective of human health must first be derived. The concentration of explosives compounds in groundwater associated with an acceptable level of risk for ingestion of drinking water by future residents is calculated using the following equation for carcinogenic chemicals and parameters presented in Table 3-8 and discussed below.

$$GW_c = \frac{1x10^{-5} * BW * AT_c * 365\ days/year}{IR * EF * ED * CSF * CF}$$

where:

GW_c	=	Chemical concentration in groundwater associated with an acceptable risk level (μg/L);
$1x10^{-5}$	=	Target risk value (unitless);
BW	=	Average body weight (kg);
AT_c	=	Averaging time (70 years for carcinogens);
IR	=	Water ingestion rate (L/day);
EF	=	Frequency of exposure (days/year);
ED	=	Duration of exposure (years);
CSF	=	Cancer slope factor $(mg/kg\text{-}day)^{-1}$; and
CF	=	Conversion factor ($mg/10^3\ \mu g$).

TABLE 3-8
Exposure Parameters for Ingestion of Chemicals in Groundwater
Future Land-Use Conditions: Residential Scenario

Parameters	Future Residents
Age Period	1-30 years
Exposure Frequency [EF](days/year or events/year)[a]	350
Exposure Duration [ED] (years)[b]	30
Ingestion of Water Parameters: Water Ingestion Rate [IR_w] (liters/day)[c]	 1.9
Body Weight [BW] (kg)[d]	48
Averaging Time [AT] (years)[e] Carcinogenic Effects Noncarcinogenic Effects	 70 30

[a]Frequency shown is the USEPA (1991a) default value for residential exposures.
[b]Duration shown is a USEPA (1989a, 1991a) default value for time spent living in one location.
[c]Water ingestion rate shown is a default extrapolated value based on USEPA (1989a, 1991a).
[d]The body weight shown is a weighted-average value calculated from USEPA (1989a, 1991a) averaging across gender and ages 1 through 30.
[e]The averaging time for carcinogenic effects is based on USEPA (1991a, 1989a) standard assumption for lifetime; for noncarcinogenic effects, the averaging time is equal to the exposure duration.

The equation used to calculate the concentrations in drinking water for noncarcinogenic chemicals is:

$$GW_{nc} = \frac{1.0 * BW * AT_{nc} * 365\ days/year * RfD}{IR * EF * ED * CF}$$

where:

RG_{nc}	=	Chemical concentration in groundwater associated with an acceptable risk level (μg/L);
1.0	=	Target hazard quotient (unitless);
BW	=	Average body weight (kg);
AT_{nc}	=	Averaging time (30 years for noncarcinogens);
RfD	=	Reference dose (mg/kg-day);
IR	=	Water ingestion rate (L/day);
EF	=	Frequency of exposure (days/year);
ED	=	Duration of exposure (years); and
CF	=	Conversion factor (mg/10^3 μg).

Drinking water exposures were evaluated for a hypothetical future resident between the ages of 0 to 30. For individuals 0-30 years of age, a time-weighted average body weight of 48 kg was used (based on data in USEPA 1989a). A drinking water rate of 1.9 liters/day was used based on assuming a consumption rate of 1 liter/day for individuals up to 10 kg (approximately 3 years of age), and a rate of 2 liters/day for those over 3 years of age. Residents were assumed to consume groundwater for 350 days/year, which is the standard USEPA (1989a, 1991) default value for residential groundwater use. In using this value, it is conservatively assumed that residents ingest drinking water at home all but two weeks a year. An exposure duration of 30 years, which is the upper-bound value for residential tenure at one residence, was assumed for future residents (USEPA 1989a, 1991). To calculate potential carcinogenic exposures for residents, the AT was equal to the USEPA (1989a, 1991) standard default of a lifetime (i.e., 70 years). To calculate the potential for noncarcinogenic exposures, the AT was equal to the duration of exposure (i.e., 30 years).

The groundwater concentrations that were calculated to be protective of residential ingestion for the explosives compounds are presented in Table 3-9. Since groundwater concentrations for RDX and 2,4,6-TNT were derived for both carcinogenic and non-carcinogenic exposures, the more conservative (the lower) ground water concentration is presented in bold type (C_{gw}). Only one groundwater concentration is presented for tetryl, since it exhibits only noncarcinogenic effects. The more conservative groundwater concentrations for each chemical were then used to derive the maximum soil concentration (i.e., soil clean-up goal), as described below.

A number of important assumptions were made in the calculation of soil remediation goals based on protectiveness of groundwater:

- The total mass of each explosives compound in the northern industrial areas is estimated to be the product of the average concentration of each explosives compound in the soil (in those areas where each explosives compound is present), the fraction of the area that is contaminated, the depth at which each explosive compound is present in soil, and the area of the northern industrial areas.

- In these calculations, it was assumed that the total mass of each explosives compound will partition to percolating rainwater at a constant rate over 30 years. The time assumption is a standard assumption used in landfill performance estimates (such as the USEPA's Vertical and

TABLE 3-9
Soil Risk-Based Remediation Goals Based on Groundwater Ingestion Exposures[a]

Chemical	Acceptable Groundwater Concentration(μg/L)		Soil Clean-Up Levels (mg/kg)	
	Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic
RDX	6	79	**10**	150
Tetryl	--	263	--	**500**
2,4,6-TNT	20	13	41	**25**

(a) Acceptable groundwater concentrations (i.e., based on a target risk of $1x10^{-5}$ for carcinogens and a hazard quotient of 1.0 for noncarcinogens) were input into an equation (see Section 3.2.4.2) to calculate an acceptable soil remediation level.

Note: The bolded values are the lower and more conservative concentrations between the carcinogenic and noncarcinogenic values.

Horizontal Spread [VHS] model). It is assumed that the total mass of each explosives compound will enter the aquifer over the 30 year time interval. Given the low organic carbon content of the subsurface soil at MAAP, a very small fraction of each explosives compound is adsorbed to the soil; and therefore, this assumption is conservative but not unreasonable.

- The total volume of groundwater into which the estimated mass of each explosives compound would mix was then estimated from the hydrologic information gathered during the RI. It was conservatively assumed that each explosives compound would mix in the volume of groundwater that consists of the sum of the volume of groundwater immediately under the northern industrial areas and the volume of groundwater that flows under the industrial area over a period of 30 years.

  - A conservative estimate for the average velocity of groundwater at MAAP is approximately 72 feet/year.

  - Using the procedures in the draft EPA Guidance document "Technical Background Document for Soil Screening Guidance" (USEPA, 1994c), a mixing depth in the aquifer of 47 feet was derived. The calculation of this mixing depth is provided in Appendix A.

- An equation for the average concentration of each explosives compound in groundwater was then derived using mass balance relations. These estimated concentrations are due to leaching of contaminants from the subsurface soil only, and do not include existing groundwater contamination or the effects of upgradient sources on groundwater quality.

The resulting equation for the concentration of each explosives compound in groundwater that corresponds to a remediation level in soil of RG_s is the following (see Appendix A for the full derivation):

$$RG_s = \frac{2 * C_{gw} * D_A \ (vT + W)}{f_{area} * D_{exp} * W * (6.2 \ x \ 10^3)}$$

where:

RG_s	=	Remediation level for each explosives compound in the soil (mg/kg);
C_{gw}	=	Acceptable groundwater concentration (µg/L) (see Table 3-9);
D_A	=	Mixing depth within the aquifer (47 ft);
v	=	Groundwater flow velocity (72 ft/yr);
T	=	Time in which the individual explosives compound leaches from the soil to the groundwater (30 yr);
f_{area}	=	Fraction of the surface area of the industrial area that contains the individual explosives compound at levels between the method detection limit (MDL) and the soil remediation level RG_s (0.005);
D_{exp}	=	Depth at which the individual explosives compound exists in soil at a concentration above the MDL (5 ft); and
W	=	Width of the industrial area in the direction parallel to groundwater flow (1,000 ft).

The values used for the above constants, as well as the rationale behind their selection, are presented in Appendix A. The soil concentrations associated with acceptable groundwater ingestion risks are presented on Table 3-9, along with associated acceptable groundwater concentrations.

3.2.5 Uncertainty Section

There is a large degree of uncertainty associated with many assumptions used in risk assessments. Consequently, it should be recognized that many uncertainties also are associated with the clean-up levels that were calculated in this evaluation. For example, uncertainties are associated with exposure assumptions that were made, the toxicity criteria that were used, as well as the groundwater fate and transport modeling. In general, the primary sources of uncertainty are the following:

- Exposure parameter estimation;
- Toxicological data; and
- Fate and transport modeling.

A complete understanding of the uncertainties associated with the clean-up levels is critical to understanding how the values should be used. Each of the sources of uncertainty listed above and associated with the clean-up levels are summarized below.

3.2.5.1 Toxicological Data. In most RAs, one of the largest sources of uncertainty is in health criteria values. Health criteria for evaluating long-term exposures such as RfDs or CSFs are based on concepts and assumptions which bias an evaluation in the direction of over-estimation of health risk. As USEPA notes in its Guidelines for Carcinogenic RA (USEPA 1986a):

> There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns and other cultural factors.

These uncertainties are compensated for by using upper-bound 95 percent upper confidence limits for cancer slope factors for carcinogens, and safety factors for reference doses for noncarcinogens. At best, the assumptions used here provide a rough but plausible estimate of the upper limit of risk (i.e., it is not likely that the true risk would be much more than the estimated risk, but it could very well be considerably lower, even approaching zero). More refined modeling in the area of dose-response calculation (e.g., using maximum likelihood dose-response values rather than the 95 percent upper confidence limits) would be expected to increase the final clean-up levels.

There are varying degrees of confidence in the weight-of-evidence for carcinogenicity of a given chemical. USEPA's (1986a) weight-of-evidence classification provides information that can indicate the level of confidence or uncertainty in the data obtained from studies in humans or experimental animals. For example, several of the explosives compounds that were evaluated are Class C chemicals, possible human carcinogens, for which there is limited evidence of carcinogenicity in animals. Although RDX and 2,4,6-TNT are both Class C carcinogens, as opposed to 2,4-DNT, which is a Group B2 carcinogen, the evidence for their carcinogenicity is considered to be as strong as that of 2,4-DNT. This factor should be considered when determining clean-up levels for these explosives compounds, as the chemicals with a lower certainty of carcinogenicity are driving clean-up levels.

For dermal pathways, there is uncertainty associated with the fact that there are no toxicity values (RfDs and cancer slope factors) that are specific to the dermal route of exposure. To evaluate the dermal pathway, therefore, absorbed dermal doses were combined with oral toxicity values. As described previously (see Section 3.2.3.4), the oral toxicity values, typically expressed in terms of potential (or administered) doses, should be adjusted when assessing the dermal doses, expressed as internal (or

absorbed) doses. In this assessment, absolute oral absorption fractions from the literature were used to adjust the oral toxicity criteria. The risk estimates for the dermal pathways may be over- or under-estimated depending on how closely these values reflect the difference between effects via the oral and dermal routes.

3.2.5.2 Exposure Assessment. There are several major sources of uncertainty in the exposure assessment portion of deriving clean-up levels, including the selection of input parameters used to estimate chemical intakes and the choice of fate and transport models used. The uncertainties associated with these various sources are discussed below.

The input parameter values used in the clean-up level equations to describe the extent, frequency and duration of exposure to soil and groundwater are associated with some uncertainty. In order to compensate for the unknown exposure patterns of potential future receptors in the northern industrial areas of MAAP, very conservative exposure assumptions were used, to ensure that potential future exposures would not be underestimated. For example, remediation goals were calculated to be protective of both workers working at the northern industrial areas of MAAP for 250 days/year for 25 years, as well as residents who live at the load lines and contact soil and consume groundwater 350 days/year for 30 years. In addition, assuming that residents would live at the load lines is very hypothetical and unlikely. Additional uncertainty is associated with exposure parameters for certain individuals within an exposed population that may be higher or lower than those assumed in this evaluation, depending upon their actual intake rates (e.g., groundwater ingestion rates, soil ingestion rates), nutritional status, body weights, etc. Exposure assumptions that were used were conservative, and were designed to produce a reasonable upper-bound estimate of exposure in accordance with USEPA guidelines regarding Superfund site RAs.

The assumptions used in the modeling of leaching of contaminants to groundwater are generally conservative, including the assumption that 100% of the mass of contaminants in soil eventually leaches to groundwater. In reality, a certain fraction of the contaminants biodegrade, experience other natural processes such as photolysis, or become bound to the organic material within the soil.

3.2.6 <u>Conclusions</u>

The human health-based remediation goals for explosives compounds in soil are summarized in Table 3-10 for direct exposures to soil by industrial and excavation workers and by residents, as well as for protection of groundwater. As noted earlier, the use of the more conservative values for soil remediation levels are recommended for use, so that future human health risks will not exceed a risk of 1×10^{-5} or a hazard index of 1.0. A comparison between clean-up goals associated with worker and residential soil exposures and protection of groundwater indicates that the more conservative goals are based on the protection of groundwater. As a result, as shown in Table 3-10, the soil remediation levels selected for the northern industrial areas of MAAP are 10 μg/g for RDX, 25 μg/g for 2,4,6-TNT, and 500 μg/g for tetryl.

3.2.7 <u>Mass of Soil to be Remediated</u>

The mass of soil to be remediated has been calculated based on the case in which all soil within the northern industrial areas containing explosives compounds above the soil remediation level of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds would be excavated to a maximum depth of 10 feet below the subsurface. The information collected from the Line B soil sampling (see Section 2.3.5.2) indicates that 0.25% of the total area of the northern industrial areas contains 2,4,6-TNT and RDX above the soil remediation levels of 25 μg/g and 10 μg/g, respectively. The total surface area of the northern industrial areas is approximately 460 acres. The approximate area of soil with levels of explosives compounds greater than the soil remediation levels within the northern industrial areas is

TABLE 3-10
Summary of Soil Risk-Based Remediation Goals[a]

Chemical	Soil Contact Exposures			Groundwater Exposures
	Industrial Worker	Excavation Worker	Resident	Resident
RDX	220	3,500	55	10
Tetryl	9,400	12,000	2,600	500
2,4,6-TNT	470	600	130	25

(a) The most conservative remediation goals for each receptor are presented in this table.

50,000 ft^2, therefore, the in-situ volume of soil to be excavated is 18,500 yd^3. Assuming a bulking factor upon excavation of 1.2, the total volume excavated is 22,200 yd^3. The approximate dry density for sandy soil is 125 lbs/ft^3 (Holtz and Kovacs, 1981), therefore, the total mass of dry soil is approximately 38,000 tons. This calculation does not account for soil moisture that would also be excavated.

3.3 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO-BE-CONSIDERED GUIDANCE

Section 121 of CERCLA, as amended by SARA, requires that remedial actions at Superfund sites comply with requirements or standards under Federal or State environmental laws that are "applicable" or "relevant and appropriate" to the hazardous substances, pollutants, or contaminants at a site or the circumstances of the release. ARARs are defined as cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Superfund site. ARARs are used to develop remedial action objectives, determine the appropriate extent of site cleanup, and govern implementation and operation of the selected action.

SARA amended Section 121 of CERCLA to include the following waivers for ARARs. Provided that the remedial action protects human health and the environment, requirements may be waived if:

- The remedial action is an interim measure where the final remedy will attain the ARAR upon completion;
- Compliance will result in greater risk to human health and the environment than other options;
- Compliance is technically impracticable;
- An alternative remedial action will attain the equivalent of the ARAR;
- For State requirements, the State has not consistently applied the State requirement in similar circumstances; or
- For Section 104 remedial actions, compliance with the ARAR will not provide a balance between protecting human health, welfare, and the environment at the facility with the availability of fund money for response at other facilities (this waiver is not applicable at MAAP).

"Applicable" requirements are those Federal and State requirements which are legally applicable, whether directly or incorporated by a federally-authorized State program. "Relevant and appropriate" requirements are Federal and State standards, criteria, or limitations which are not legally applicable to the site, but which address problems so similar that their application is appropriate. The determination that a requirement is relevant and appropriate involves the comparison of a number of site specific factors with those addressed in the regulatory requirements, including the physical circumstances of the site, hazardous substances present at the site, and characteristics of the remedial action. TBC materials are non-promulgated advisories or guidance issued by Federal or State government that are not legally binding and do not have the status of ARARs. TBCs may be used in conjunction with ARARs to determine the necessary level of cleanup for protection of health and the environment.

Selection of ARARs is dependent on the hazardous substances present at the site, the site characteristics and location, and the actions selected for a remedy. Thus, these requirements may be chemical-, location-, or action-specific. Chemical-specific ARARs are health- or risk-based concentration limits set for specific hazardous substances, pollutants, or contaminants in various environmental media. These requirements provide protective site cleanup levels, or a basis for calculating cleanup levels, for chemicals of concern in the designated media. Chemical-specific ARARs are also used to indicate an acceptable level of discharge to determine treatment and disposal requirements for a particular remedial activity and to assess the effectiveness of a remedial alternative. In the event that a chemical has more than one requirement, the most stringent of the requirements is applied.

Location-specific ARARs set restrictions on the types of remedial activities which can be performed based on site-specific characteristics or location. Alternative remedial actions may be restricted or precluded based on Federal or State siting laws for hazardous waste facilities, and proximity to wetlands or floodplains or to man-made features such as existing landfills, disposal areas, and local historic buildings. Location-specific ARARs provide a basis for assessing restrictions during the formulation and evaluation of potential site-specific remedies.

Action-specific ARARs set controls or restrictions on the design, implementation, and performance of waste management actions. They are based on specific remedial activities which may be selected to accomplish cleanup objectives. After remedial alternatives are developed, action-specific ARARs which specify performance levels, actions, or technologies, as well as specific levels for discharge or residual chemicals, provide a basis for assessing the feasibility and effectiveness of the remedial alternatives. The regulatory agencies responsible for the site make the final determination on the applicability or relevance and appropriateness of a requirement based on such factors as the characteristics of the remedial action and physical circumstances of the site.

3.4 CHEMICAL-SPECIFIC ARARs

The contaminants of concern in the soil at the northern industrial areas are limited to explosives compounds, particularly 2,4,6-TNT and RDX.

3.4.1 Soil ARARs

There are no Federal or Tennessee regulations for the concentrations of explosives compounds in soil. Consequently, risk-based soil remediation levels have been developed, as presented in Section 3.2. The information in this section assesses the fate of the explosives-contaminated soil with regard to the requirements of RCRA.

Waste treatment standards that often include contaminant concentration criteria have been established under RCRA for certain hazardous wastes that are otherwise banned from land disposal (40 CFR 268). However, the applicability of these cleanup standards to CERCLA sites is an issue that the USEPA is currently addressing (54 FR 41566, October 10, 1989). Since some of the remedial options could involve treatment of the soil and subsequent land disposal, the RCRA requirements were reviewed to determine if they would be ARARs and result in chemical-specific treatment standards.

The primary requirement affecting the classification of the soil under RCRA is to determine whether the materials are classified as hazardous. According to 40 CFR Part 268, Subtitle C, Section 261.32, wastewater treatment sludge from the manufacture and processing of explosives compounds is a listed waste as Hazardous Waste No. K044. Pink/red water from 2,4,6-TNT operations is a listed waste as Hazardous Waste No. K047. The first issue to be addressed is whether MAAP falls under the category of the specific industrial source for which the wastes were listed. According to the RCRA Background

Document (1980)[2], the explosives industry is comprised of those facilities engaged in the manufacture and LAP of high explosives, blasting agents, propellants, and initiating compounds. Under this definition, MAAP clearly falls under the specific source in question; therefore, the above-listed materials at MAAP are listed hazardous wastes.

The second issue is to determine if the soil also constitutes a hazardous waste. The USEPA uses the "contained in" rule when dealing with environmental media contaminated with hazardous waste. Unlike the "mixture" or "derived from" rules, the contained in rule is not codified in Federal regulations. However, it is the policy of the USEPA to require that soil containing a listed waste be managed as a hazardous waste until it no longer contains that listed waste (Telephone conversation with Amy Norgren, USEPA, RCRA Hotline, 1991).

For the particular case of soil containing explosives compounds, the USEPA has not established a policy for determining when the soil is no longer a hazardous waste. It is therefore left for State or regional interpretation. For other hazardous wastes which are listed because of a RCRA characteristic (such as ignitability, corrosivity, etc.), the soil may be deemed non-hazardous if it does not have the characteristic for which the waste was listed. In other cases, a risk assessment is performed to determine the concentration of the listed waste in soil which results in an unacceptable health risk.

Both of these listed wastes were listed solely because of the characteristic of reactivity and not for specific chemical constituents (see, *e.g.*, 53 Federal Register 17604, May 17, 1988). A material can exhibit the characteristic of "reactivity" in several ways as defined by RCRA. For explosives compounds, the following two definitions of a reactive material are applicable:

- It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement [40 CFR 261.23(a)(6)]; or

- It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure [40 CFR 261.23(a)(7)].

Extensive testing has been conducted by the Army to define the reactivity of explosives-contaminated soil to flame and shock stimuli. The explosives compounds evaluated included 2,4,6-TNT, RDX, and HMX. The results indicated that soil containing less than 15 percent explosives compounds will not react positively to induced shock, and soil containing less than 12 percent explosives will not react explosively when subjected to submerged flame initiation (Arthur D. Little, Inc., 1987). As a conservative guideline, the Army generally uses a total explosives concentration of 10 percent as a control limit. The maximum concentration of explosives compounds detected in any of the samples collected from the northern industrial areas was approximately 1 percent, which is well below reactive levels. Since the K044, K045, and K047 wastes were listed because of the characteristic of reactivity and the soil at the northern industrial areas is not reactive, the soil is not a listed hazardous waste.

It is possible that although the soil is not reactive and is not a listed waste, it still may constitute a hazardous waste by virtue of the RCRA characteristics of ignitability, corrosivity, or toxicity. The rationale for further screening of the soil under RCRA requirements is as follows:

- The only material in question is soil. Therefore, the characteristics of ignitability and corrosivity may be eliminated without testing.

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[2]Background Document, Resource Conservation and Recovery Act, Subtitle C, Identification and Listing of Hazardous Waste, Section 261.31 and 261.32, Listing of Hazardous Waste (Finalization of May 1980 Hazardous Waste List), U.S. Environmental Protection Agency, Office of Solid Waste, November 14, 1980.

- The RCRA characteristic of toxicity is typically determined by the Toxicity Characteristic Leaching Procedure (TCLP) and analysis of the leachate. For the explosives-contaminated soil in the northern industrial areas, the only analytes of concern which have regulatory levels are nitrobenzene and 2,4-DNT. If the concentration of nitrobenzene in the extract exceeds 2 mg/L or the concentration of 2,4-DNT exceeds 0.13 mg/L, then the soil would be classified as a hazardous waste by virtue of toxicity.

The second major regulatory requirement to be met in proper disposal of the soil are the Land Disposal Restrictions (LDRs) (40 CFR Part 268). The USEPA has promulgated these restrictions in response to the Hazardous and Solid Waste Amendments (HSWA) of 1984, which prohibit the land disposal of hazardous wastes. The LDRs set levels or methods of treatment which reduce the toxicity and/or likelihood of migration of hazardous wastes, and only those wastes which meet the treatment standards may be land-disposed.

Originally, K044 and K047 listed wastes fell into the First-Third Scheduled Wastes rule, wherein the USEPA promulgated a treatment standard of "No Land Disposal" (53 FR 31138, August 17, 1988). This ruling precluded the legal land-disposal of these wastes, regardless of how much treatment they receive. This ruling was later clarified (54 FR 18836, May 2, 1989); the USEPA stated that the original ruling was made on the premise that the characteristic of reactivity be removed before the waste is disposed.

The LDRs for Third-Third Scheduled Wastes (55 FR 22520, June 1, 1990, and codified in 40 CFR Part 268) revoked the "No Land Disposal" treatment standard. The USEPA is currently promulgating "deactivation" to remove the characteristics of ignitability, corrosivity, and reactivity as the treatment standard. A list of specific technologies is supplied, including incineration, to meet the deactivation requirements; however, use of these specific technologies is not mandatory provided deactivation (i.e. removal of hazardous characteristics) is achieved.

In this case, the soil is not capable of displaying the characteristic of reactivity, based on the chemical data obtained during the RI. Therefore, it appears that the soil which does not display the characteristic of toxicity may be land-disposed. The soil which displays the characteristic of toxicity must meet the promulgated treatment standard prior to land-disposal; i.e. the soil must be treated until the soil no longer displays the characteristic of toxicity.

3.5 LOCATION-SPECIFIC ARARs

Location-specific ARARs set restrictions on remedial action activities depending on the characteristics of a site or its immediate environs. Much of the information regarding characteristics of MAAP was provided by officials from the State of Tennessee. Table 3-11 lists regulations that may be considered ARARs for MAAP.

3.5.1 Faults

There are no faults in the immediate area of MAAP (Tennessee Geologic Survey, 1978). However, the primary concern at the installation is its proximity to the New Madrid Seismic Zone, one arm of which extends almost to Dyersburg, Tennessee, 40 miles northeast of the plant (Stevens, 1989). The Tennessee Earthquake Center records an average of 150 earthquakes a year in this zone; consequently, Milan is in close proximity to major seismic activity (Algermissen and Hopper, 1984).

The Earthquake Center has defined the seismic zone in which MAAP is located as Seismic Zone 2. This zone is at moderate risk from a large earthquake in the New Madrid Seismic Zone (Stevens,

1989). If any remedial action alternatives requiring site modification are selected, the RCRA regulation governing placement of hazardous wastes in fault zones will be a relevant and appropriate requirement.

3.5.2 Wetlands and Floodplains

The Flood Hazard Boundary Map and Flood Insurance Rate Maps, maintained by the Federal Emergency Management Agency (FEMA), indicate that there are some areas of MAAP that are located within the approximate 100-year floodplain (FEMA, 1988a; FEMA, 1988b). The Flood Plain Information Report (USACE, 1974) also identifies some additional areas at MAAP that are subject to flooding during a 100-year flood (ORNL, 1990). Therefore, the regulation prohibiting site modifications in a 100-year floodplain will be an ARAR for MAAP.

Three major watersheds (the Middle Fork of the Forked Deer River, Wolf Creek, and Rutherford Fork of the Obion River) and one minor watershed (Hall's Branch of Johns Creek) drain MAAP (Blaylock, 1978; USAEC, 1988a). Areas at MAAP subject to flooding after heavy rains, generally four inches or more in twelve hours or less, include portions of Hall's Branch and Wolf Creek (Blaylock, 1978; USACE, 1978). Flooding of the installation that occurs during rainy seasons could cause the off-post migration of surface soil contamination (USAEC, 1988a; USACE, 1978).

Wetlands occur throughout the site (Powers, 1989). The State of Tennessee State Conservation Department classifies wetlands as areas having hydric soil and woody vegetation, therefore meeting the requirements defining a wetland according to the U.S. Department of Agriculture (Ellis, 1991). If any remedial actions are contemplated that would impact wetland areas, the regulations found in Executive Order 11988 and Executive Order 11990 will be ARARs.

3.5.3 Wilderness Areas, Wildlife Refuges, and Scenic Rivers

There are no wilderness areas, wildlife refuges, or wild or scenic rivers inside the plant boundaries (Hurst, 1989); however, under the Tennessee Water Quality Control Act, the Tennessee Water Control Board has delegated the three primary streams in and near MAAP (the Rutherford Fork of the Obion River, the East Fork, and Wolf Creek) for the following uses: fish and aquatic life, recreation, irrigation and livestock watering, and wildlife (TDHE, 1991). If any remedial actions are contemplated that would impact these areas, the regulations found in the Fish and Wildlife Coordination Act will be ARARs.

3.5.4 Historic Sites and Archaeological Findings

There are three known archaeological sites at MAAP located on high ground overlooking Wolf Creek (Blaylock, 1978). One site is located in a cultivated area. Materials consist mostly of middle Archaic artifacts. The sites have not been extensively examined and, therefore, their exact importance is unknown (Blaylock, 1978). An archaeological overview and management plan has been developed for MAAP; however, it does not provide conclusive information and a complete archaeological investigation needs to be conducted (Smith, 1989).

There is one historical structure of significance on MAAP, the Browning House, childhood home of Gordon Browning who was governor of Tennessee in 1937-38 and 1942-52 (MacDonald and Mack Partnership, 1984). The building is located adjacent to Line Z in the northwest portion of the installation. The Browning House has been entered into the National Register of Historic Places as provided for in the Preservation Act of 1966 (MacDonald and Mack Partnership, 1984). If any remedial actions are considered that would impact the archaeological sites or the historic home, the regulations listed in Table 3-11 will be ARARs.

TABLE 3-11
Identification of Location-Specific ARARs

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	RCRA - Location Standards, Permitted Hazardous Waste Facilities (40 CFR 264.18)	Relevant and appropriate	This regulation prohibits new treatment, storage, or disposal of hazardous waste within 61 meters (200 feet) of a fault displaced in Holocene time.
	RCRA - Location Standards, Permitted Hazardous Waste Facilities (40 CFR 264.18)	Relevant and appropriate	This regulation outlines the requirements for constructing a RCRA facility on a 100-year floodplain. The facility must be designed, constructed, operated, and maintained to avoid washout by a 100-year flood, unless waste may be removed safely before floodwater can reach the facility or no adverse effects on human health and the environment would result if washout occurred.
	Executive Order 11988: Floodplain Management (40 CFR 6, Appendix A)	Relevant and appropriate	Federal agencies are required to reduce the risk of flood loss, to minimize the impact of floods, and to restore and preserve the natural and beneficial values of floodplains.
	Executive Order 11990: Protection of Wetlands (40 CFR 6, Appendix A)	Relevant and appropriate	Federal agencies are required to minimize the destruction, loss, or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands.
	Clean Water Act, Section 404 (40 CFR 230.10; 33 CFR 320-330)	Relevant and appropriate	This regulation prohibits discharge of dredge or fill material into wetlands without a permit. It provides for the enhancement, restoration, or creation of alternate wetlands.
	U.S. Army Corps of Engineers Nationwide Permit Program (33 CFR 330)	Relevant and appropriate	This program prohibits any activity that adversely affects a wetland if a practicable alternative is available that has less effect.
	Fish and Wildlife Coordination Act (16 USC 661 et seq.)	Relevant and appropriate	Actions that will impact fish and wildlife must include action to protect affected fish and wildlife resources. This law prohibits diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife.

TABLE 3-11 (continued)
Identification of Location-Specific ARARs

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	National Archaeological and Historic Preservation Act (16 USC 470 et seq., 36 CFR 800); National Historic Landmarks Program (36 CFR 65); National Register of Historic Places (36 CFR 60)	Relevant and appropriate	Federal agencies must take action to recover and preserve artifacts within areas where action may cause irreparable harm, loss, or destruction of significant artifacts. Federal agencies must identify possible effects of proposed remedial activities on historic properties, and measures must be implemented to minimize or mitigate potential effects.
	Endangered Species Act of 1973 (16 USC 1531 et seq.; 50 CFR 402)	Relevant and appropriate	This law requires that action be taken to conserve endangered or threatened species. In addition, actions must not destroy or adversely modify critical habitat. Consultation with the Department of the Interior is required to ascertain that proposed actions will not affect any listed species.
State Regulatory Requirement	Tennessee Nongame and Endangered or Threatened Species Conservation Act (Tennessee Code Annotated, Section 70.8101)	Relevant and appropriate	This regulation requires that consideration be given to threatened or endangered species.

3.5.5 Rare, Threatened or Endangered Species

Rare or endangered species of animals have not actually been observed at MAAP; however, a 1978 report prepared by the Department of the Army recommends that four species of birds should be actively investigated to establish their status at the site. These species include: Sharp-shinned Hawk (Accipiter striatus velox), Cooper's Hawk (Accipiter cooperi Bonaparte), BeWick's Wren (Thryomanes bewickii), and the Grasshopper Sparrow (Ammodramus savannarum pratensis). These species appear on the State and Federal endangered list and the National Audubon Society's Blue List. Several endangered, threatened, rare, and special concern species occur in Gibson and Carroll County, Tennessee; however, further site study is needed to determine their status at MAAP and in the surrounding areas (TDEC, 1989a; Pitts, 1989).

One State-listed threatened plant, the Compass Plant (Silphium laciniatum), has been observed near the roadside by the boundary fence, on the southeast corner of MAAP (Eagar, 1989; Tennessee Department of Conservation, 1989b). The Compass Plant has also been observed on the extreme southern edge of MAAP within a few hundred feet of the boundary fence (Blaylock, 1978).

If remedial action alternatives requiring site modifications are selected, regulations found in the Endangered Species Act of 1973 may be relevant and appropriate. In addition, any regulation cited in the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act (in Tennessee Code Annotated Section 70.8101) will be relevant and appropriate.

3.6 ACTION-SPECIFIC ARARs

Based on the remedial alternatives for soil remediation developed in Section 5, certain action-specific ARARs may be applicable, depending on the actual alternative selected. The following paragraphs provide information concerning action-specific ARARs for capping, excavation, incineration, and biological treatment. Action-specific ARARs, which include general RCRA requirements applicable to site remediation, are summarized in Table 3-12.

As discussed above, the soil is not a RCRA listed waste, nor has the contaminated soil exhibited the characteristic of reactivity that would make Federal RCRA and Tennessee hazardous waste requirements applicable. However, these requirements are relevant and appropriate. Therefore, substantive elements of the Federal RCRA requirements for closure of surface impoundments and treatment, storage, and disposal (TSD) facilities are ARARs.

Various Tennessee regulations would apply to actions taken to remediate the soil in the northern industrial areas. Tennessee Hazardous Waste Management Act (Title 68, Chapter 46), which governs the storage, treatment, and disposal of hazardous wastes would be applicable. This law defines "hazardous waste" and includes permitting requirements for hazardous waste facilities. Actions would also be required to comply with Tennessee Solid Waste Processing and Disposal Regulations (Rule 1200-1-7), which specify permitting, siting, design, and closure requirements for various disposal facilities. The following sections briefly describe requirements that would have to be met by specific remedial actions taken at the site.

3.6.1 Capping

Capping involves covering a site to reduce direct exposure to contaminants and to minimize infiltration of precipitation and subsequent vertical migration. RCRA regulations allow closure with waste

and contaminated soil either removed (clean closure) or intentionally left in place. The design and maintenance requirements for caps are contained in 40 CFR 264.228 and include the following:

- Run-on and run-off must be controlled to prevent erosion of or damage to the cap;
- The cap must provide long-term minimization of liquid infiltration, and have a permeability less than that of the natural subsoil;
- The cap must function with minimal maintenance;
- The cap must accommodate settling and subsidence while retaining integrity; and
- Post-closure monitoring and maintenance must be provided.

These criteria will be considered as potential design guidelines.

Capping would probably include grading, construction, and possibly excavation activities that could generate non-point source emissions of particulates and pollutants. Action-specific ARARs for these activities are discussed below.

A landfill or cap constructed at the site would be required to comply with Tennessee Solid Waste Processing and Disposal Regulations (Rule 1200-1-7). This rule specifies permitting, siting, design, monitoring, closure, and post-closure requirements for various disposal facilities, including landfills.

3.6.2 Excavation

Excavation could be used in conjunction with either incineration or biological treatment of soil. It is anticipated that explosives-contaminated soil would be removed using conventional equipment.

Activities associated with excavation could produce airborne pollutants and particulates. The Tennessee Air Pollution Control Regulations establish grain loading and process weight rate limits for particulate emissions [Rule 1200-3-7.03(2)]. Acceptable grain loading rates range from 0.02 to 0.25 grains per dry standard cubic foot (dscf) depending upon the process weight rate input.

If excavation activities within the northern industrial areas disrupt over 5 acres of land, the substantive requirements of the Tennessee Water Pollution Control Regulations' general stormwater permit program for construction activities (Rule 1200-4-10.05) must be met. This permit program requires that a management plan be developed to control contaminant migration in stormwater runoff.

Excavation of explosives-contaminated soil at the northern industrial areas may generate soil that displays the characteristic of toxicity and therefore would constitute a hazardous waste. Because of this, requirements of 40 CFR 264 pertaining to Standards Applicable to Generators of Hazardous Waste may be relevant and appropriate to excavation actions undertaken at the site.

3.6.3 Incineration

Incineration would involve treating soil using an incinerator that is transported to the site or built on site. Federal RCRA regulations for hazardous waste incinerators are found in 40 CFR 264 Subpart O. Under these regulations, certain exemptions apply to incinerators that destroy waste that is listed solely

TABLE 3-12
Identification of Action-Specific ARARs

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	Resource Conservation and Recovery Act (RCRA), RCRA Subtitle D (40 CFR 260)	Relevant and appropriate	RCRA regulates the generation, storage, and disposal of hazardous waste. CERCLA specifically requires (in Section 104(c)(3)(B)) that substances generated during remedial actions be disposed at facilities in compliance with RCRA. Substances which do not exhibit hazardous characteristics, as outlined in RCRA, may be disposed as a solid waste in compliance with Subtitle D of RCRA.
	RCRA - Identification and Listing of Hazardous Waste (40 CFR 261)	Applicable	This regulation provides guidance for classifying wastes as hazardous under RCRA.
	RCRA - Closure and Post-Closure (40 CFR 264.110 - 264.120)	Relevant and appropriate	This regulation details specific requirements for closure and post-closure of hazardous waste facilities.
	RCRA - 40 CFR 264, Subpart N (Landfills) and Subpart O (Incinerators)	Relevant and appropriate	This regulation establishes minimum national standards which define the acceptable management of hazardous waste in landfills and incinerators.
	RCRA - Land Disposal Restrictions (40 CFR 268.43)	Relevant and appropriate	This regulation establishes a timetable for restriction of burial of wastes and other hazardous materials, as well as Best Demonstrated Available Technology standards.
State Regulatory Requirement	Tennessee Air Pollution Control Regulation - Fugitive Dust Standard (Rule 1200-3-8.01)	Applicable	This regulation provides for a visible emission limit from any air contaminant source of an opacity of 20% for an aggregate of more than 5 minutes in any 1 hour or more than 20 minutes in any 24-hour period.
	Tennessee Air Pollution Control Regulations - Visible Emissions (Rule 1200-3-5.01)	Applicable	This regulation provides for no visible emissions allowance at the property line.

TABLE 3-12 (Continued)
Identification of Action-Specific ARARs

Authority	Requirement	Status	Requirement Synopsis
State Regulatory Requirements, continued	Tennessee Air Pollution Control Regulations - Particulate Emissions (Rule 1200-3-7.03(2))	Applicable	This regulation establishes grain loading and process weight rate limits for particulate emissions.
	Tennessee Air Pollution Control Regulations - Non-Process Emission Standards (Rule 1200-3-6.02(3))	Applicable	This regulation establishes limits for particulate emissions based on a percent of the charging rate to the unit (e.g., incinerator).
	Tennessee Water Pollution Control Regulations - General Stormwater Permit for Construction Activities (Rule 1200-4-10.05)	Applicable	This regulation requires a general NPDES permit for stormwater discharges associated with construction activities that disrupt five or more acres of land. A management plan must be developed to manage stormwater runoff and prevent contaminant migration.
	Tennessee Water Pollution Control Regulations - General Stormwater Permit for Industrial Activities (Rule 1200-4-10.04)	Applicable	This regulation requires a general NPDES permit for stormwater discharges associated with industrial activities, including incineration. A management plan must be developed to manage stormwater runoff and prevent contaminant migration.
	Tennessee Water Quality Standards (Rule 1200-4-3)	Applicable	Provides for the prevention, abatement, and control of water pollution problems to protect existing water quality and protect public health and welfare. Specific criteria for physical and chemical parameters are given for waters depending on stream use (e.g., recreation, aquatic life, etc.). Waste discharge (including industrial wastewater, such as incinerator scrubber blowdown water) shall be treated as necessary to comply with water quality standards.

TABLE 3-12 (Continued)
Identification of Action-Specific ARARs

Authority	Requirement	Status	Requirement Synopsis
State Regulatory Requirements, continued	Tennessee Effluent Limitations and Standards (Rule 1200-4-5)	Applicable	Requires that new industrial wastewater discharges meet standards of performance for new sources pursuant to Federal Water Pollution Control Act. Chemical-specific effluent limitations for industrial wastewater treatment plants are given. Requires treatment of effluents to comply with pollutant standards and water quality standards.
	Tennessee Solid Waste Disposal Act (Title 68, Chapter 31)	Applicable	May apply to non-hazardous residuals generated in any treatment process. This act provides for safe disposal to prevent, control, and abate pollution caused by solid waste. Air, water, and soil contamination must be prevented by new disposal facilities. Permitting, operating, and maintenance requirements are stipulated.
	Tennessee Hazardous Waste Management Acts (Title 68, Chapter 46)	Applicable	Governs the storage, treatment, and disposal of hazardous wastes. Defines "hazardous waste" and establishes authority for determining criteria for hazardous wastes. Defines "hazardous substance" as those in Section 101 of Public Law 96-510. Includes permitting requirements for hazardous waste facilities, and establishes goals of reducing and preventing generation of hazardous wastes.
	Tennessee Solid Waste Processing and Disposal Regulations (Rule 1200-1-7)	Applicable	Gives specific permitting, siting, design, monitoring, closure, and post-closure requirements for various disposal facilities, including landfills and incinerators.
	Tennessee Water Quality Control Act (Tennessee Code Annotated, Section 69)	Relevant and appropriate	This law requires a "no discharge" permit for operation of a wastewater treatment system used to treat recycled water when the treatment system is separate from the process equipment which generates the wastewater.

for reactivity and that contains none of the constituents listed in 40 CFR 261, Appendix VIII. The RCRA requirements for incinerators include:

- Waste analysis prior to the startup of incineration and periodically thereafter;
- Treatment of principal organic hazardous constituents (POHCs) to a destruction and removal efficiency (DRE) of 99.99 percent;
- Specific stack emissions controls for hydrochloric acid, particulates, and carbon monoxide; and
- Incineration only when operating within design conditions.

To meet the DRE performance requirements, testing of ash from the incinerator is required. The ash must also be tested to demonstrate that the residue is not a hazardous waste, according to RCRA definitions. If the residue is determined to be hazardous, it must be managed in accordance with the applicable requirements of RCRA found in 40 CFR Parts 262-266.

Applicable or relevant and appropriate Tennessee Solid and Hazardous Waste Regulations will be complied with.

The Federal Clean Air Act and Tennessee Air Pollution Control Regulations [Rule 1200-3-6.02(3)] would be applicable to stack emissions resulting from incineration. The requirements are extensive and include providing the highest and best practicable treatment of air contaminant emissions, complying with specific emission standards, and providing for monitoring and testing. The Tennessee Air Pollution Control Regulations establish particulate emission limits based on a percentage of the charging rate to the unit. Particulate emissions limits are 0.2 percent of the charging rate for a charging rate of 2,000 pounds/hour or less to the incinerator; particulate emissions from incinerators charging over 2,000 pounds/hour are limited to 0.1 percent of the charging rate.

Incineration activities would have to comply with substantive requirements of the Tennessee Water Pollution Control Regulations' general stormwater permit program for industrial activities (Rule 1200-4-10.04). This permit program requires that a management plan be developed to control contaminant migration in stormwater runoff. Tennessee Water Quality Standards (Rule 1200-4-3), which requires treatment of wastewater to comply with water quality standards, would also be applicable. This rule would require incinerator scrubber blowdown water to be treated as necessary prior to discharge. An incinerator would be considered a new source of industrial wastewater and would thus be required to comply with Tennessee Effluent Limitations and Standards (Rule 1200-4-5). This requires new sources to meet certain chemical-specific effluent limitations and to meet standards of performance for new sources. Siting, permitting, operation, closure, and post-closure of an incinerator must comply with Tennessee Solid Waste Processing and Disposal Regulations (Rule 1200-1-7). Disposal of treatment residuals generated by incinerators (or any other treatment process) would be governed by the Tennessee Solid Waste Disposal Act (Title 68, Chapter 31). This law applies to non-hazardous residuals generated by any treatment process and provides for the safe disposal to prevent, control, and abate pollution caused by solid waste. Permitting, operating, and maintenance requirements are stipulated.

3.6.4 <u>Biological Treatment</u>

No action-specific ARARs have been identified for biological treatment of soil.

4.0 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

The potential risks posed by explosives-contaminated soil around the northern industrial areas at MAAP indicate that remediation of the soil may be necessary.

The purpose of this Focused FS is to identify and evaluate technologies and remedial action alternatives that may be applied to treat or contain contaminants in the soil around the northern industrial areas. Under consideration are technologies which would reduce or eliminate contaminant mobility to groundwater and prevent exposures to contaminants in the surface soil. This Focused FS, particularly Section 6, provides detailed performance and cost information to evaluate the most promising remedial options and the cost-effectiveness of each alternative.

Potential remedial technology types and associated process options within each of the general response categories are identified and evaluated in this section. General response actions are broad remedial approaches capable of meeting remedial action objectives. Technology types are general categories which fall within a general response action. Process options are specific processes within each technology. Applicability to specific chemical contaminants within the soil at the northern industrial areas, as well as the ability to satisfy remedial action objectives, are considered in selecting the technology types and associated process options.

4.1 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

This section discusses general response actions, which are broad remedial approaches potentially applicable to the explosives-contaminated soil at the northern industrial areas. Although an individual response action may be capable of satisfying further risk-reduction goals, combinations of response actions may be required to provide a complete remedial action. General response actions were selected for the explosives-contaminated soil at the northern industrial areas in accordance with methods presented in the USEPA's Interim Final Edition of "Guidance for Conducting RI/FS Under CERCLA," October 1988 (USEPA, 1988a).

General response actions applicable to the explosives-contaminated soil at the northern industrial areas are as follows:

No Action - CERCLA, as amended, and the NCP require the evaluation of a No Action alternative as a baseline for comparison with other remedial technologies. The No Action alternative does not involve any remedial actions, but could include environmental monitoring. Five-year reviews of site conditions would be required by CERCLA because contamination would remain at the site.

Limited Action - Limited Action technologies do not reduce the toxicity, mobility, or volume of contamination, but are implemented to reduce the probability of physical contact with contaminated media. Limited Action technologies consist of long-term monitoring activities, physical barriers, and administrative actions (formalized in Memoranda of Agreement with regulatory agencies) such as increased installation security which would reduce the potential for exposure to contaminated media. Limited Action technologies also could inform the public, provide a database of information about the site, and evaluate changes in site conditions over time.

Containment - Containment technologies are implemented to reduce contaminant mobility and eliminate potential exposure and transport pathways, but do not necessarily affect the toxicity or volume of contaminants. For soil, these technologies are designed to limit infiltration, minimize or prevent leachate

generation, and control surface runoff of contaminants. Most containment technologies require continual monitoring to ensure that the remedial measures are performing within design parameters.

Removal - Removal involves excavation of the existing contaminated soil. Removal of contaminated soil above the risk-based level of 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds would reduce the risk posed to workers by the contaminated soil and would reduce the leaching of contaminants to groundwater such that no adverse health effects would result from ingestion of downgradient groundwater. Removal technologies would not treat contaminated materials, but could be used in conjunction with on-site or off-site treatment and/or disposal technologies as a permanent remedy.

Ex-Situ Treatment - Various technologies could be used to treat contaminated surface and subsurface soil. These technologies include alternatives which would eliminate or minimize the need for long-term management, and alternatives which would effectively treat soil at the site and reduce the toxicity, mobility, or volume of the contaminants through treatment. Prior to ex-situ treatment, soil would be excavated under the removal general response action. Thermal, biological, chemical, and/or physical treatment processes could then be used to remove the explosives compounds from the contaminated soil. The treated material would then be disposed either on or off site.

In-Situ Treatment - In-situ treatment of soil includes chemical, physical, and biological technology types. These methods could treat both the surface soil and subsurface soil. In-situ soil treatment would minimize the need for long-term management and could potentially be used to treat soil as a primary component in addressing the principal threats at the site. In-situ treatment also eliminates the need for excavation of soil and disposal of treatment residues.

Off-Site Treatment - Off-site treatment involves the destruction of contaminated soil or treatment residuals in a permitted waste treatment facility. The most likely type of off-site soil treatment would be incineration.

Disposal - Disposal technologies involve the storage of soil or treatment residuals in a permitted storage facility or disposal of contaminated soil or treatment residuals in a landfill. The land disposal of hazardous waste is strictly regulated by LDRs promulgated under HSWA. Regulatory requirements would be considered when disposing of soil or treatment residuals.

4.2 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Process options within potential technology types are screened on the basis of implementability, effectiveness, and cost. For the implementability criterion, the following factors were considered:

- Site characteristics may limit the constructability or effective functioning of the technology. For example, source control technologies may be hampered by the large number of small areas to be remediated at the northern industrial areas. As discussed in Section 3, as much as 38,000 tons of soil would need to be excavated to treat the soil contaminated with explosives compounds.

- Waste characteristics may limit the use or have an adverse impact on the effective functioning of the technology. The effectiveness of soil treatment technologies may be limited by the concentration of contaminants.

- Required equipment should be available to implement each process option.

- Capacity of on-site or off-site treatment or disposal facilities should be sufficient to implement any treatment or disposal options.

- Permits may be required for on-site or off-site treatment, transport, disposal, or construction.

As discussed above, many technology types could be implemented with a number of process options. If process options are sufficiently similar that the selection of one would not limit the evaluation of the technology type, then one representative process option was identified. If, however, the performance, cost, or implementation of process options was sufficiently different, then more than one process option was selected.

The following factors were considered under the effectiveness criterion:

- The reliability in meeting chemical-specific ARARs or human health-based risk levels, including the potential threat to groundwater. Process options that cannot achieve the remedial action objectives would be eliminated.

- The degree of permanent reduction in toxicity, mobility, or volume achieved through treatment of the waste. As required by CERCLA, process options which achieve reduction in these characteristics would be given preference.

- The long-term risks due to treatment residuals or containment systems.

- The risks to the public, workers, or the environment during construction and implementation of the process option.

Cost was considered qualitatively in the screening of process options, with only the relative magnitude of capital and O&M costs being considered. Technology types and process options which have potential applicability based on this initial screening are assembled and screened in greater detail in Sections 5 and 6.

4.2.1 No Action

CERCLA, as amended, and the NCP require the evaluation of a No Action alternative as a baseline for comparison with other remedial technologies. The No Action alternative does not involve any remedial actions, but could include environmental monitoring. Five-year reviews of site conditions would be required by CERCLA because contamination would be allowed to remain at the site.

Description - No Action is not a technology category but does provide a baseline against which all other alternatives may be compared. This response does not involve remedial activity, monitoring, or restrictions.

Initial Screening - No Action does not reduce the toxicity, mobility, or volume of contamination. As required by the NCP and CERCLA as amended, however, the No Action alternative is retained for consideration in the alternatives assembly.

4.2.2 Limited Action

Limited Action consists of long-term monitoring activities, physical barriers, and administrative actions such as increased installation security which would reduce the potential for exposure to

contaminated media. Limited Action would also include a public information program, provide a database of information about the site, and evaluate changes in site conditions over time.

4.2.2.1 Monitoring. Description - Monitoring programs including soil sampling, air sampling, and groundwater monitoring could be implemented in conjunction with the remedial actions. Monitoring does not actively prevent exposure to contaminants, nor does it reduce contaminant toxicity, mobility, or volume. However, monitoring could be used in combination with other remedies as a means to evaluate the short-term impacts and long-term effectiveness and permanence of these remedies. Soil and air sampling are discussed in Section 4.2.4, under Soil Removal/Excavation.

Groundwater monitoring could be used to evaluate the extent to which contaminants are leaching from the soil to the groundwater. Downward leaching of contaminants and transport of contaminants in the aquifer could be monitored with periodic sampling of groundwater monitoring wells.

Initial Screening - Monitoring programs use standard sampling equipment and are relatively easy to implement, but would require long-term management efforts.

Under the Limited Action alternative, groundwater monitoring would include determination of horizontal and vertical contaminant gradients in the aquifer and any changes in contaminant distributions in the aquifer over time. Therefore, data from groundwater sampling around the northern industrial areas and/or any containment option would be utilized to evaluate the effectiveness of the remedial actions. Groundwater monitoring is retained for further consideration in the alternatives assembly.

4.2.2.2 Administrative Actions. Description - Administrative actions include institutional restrictions, access restrictions, and public education. Institutional restrictions would involve controlling access to contaminated areas by implementing administrative policies which specify access controls, long-term maintenance, and monitoring to be implemented at MAAP. Administrative policies of interest would include restricting future property uses within contaminated areas to prevent residential or agricultural land use of the northern industrial areas.

Access restrictions would involve controlling access to contaminated areas by installing physical boundaries and/or signs around the contaminated areas of the northern industrial areas.

An increased public awareness of the hazards present at the site can be achieved through public education. This consists of public meetings, presentations at local schools, press releases, and posting of signs.

Initial Screening - Institutional restrictions, access restrictions, and public education would not reduce toxicity, mobility, or volume of contaminants; however, they would help to control the potential for future exposure to explosives contamination at the northern industrial areas. These actions are retained for consideration in the alternatives assembly.

4.2.3 Containment

Containment refers to passive controls which would isolate contaminants in soil from the environment to minimize the potential for exposure and/or transport. These technologies would isolate contaminants to prevent direct contact, incidental ingestion, and other human exposures, and/or attempt to control contaminant migration from leaching, erosion, or runoff.

4.2.3.1 Engineered Cap. Description - Capping is a method of containing contaminated materials. Engineered caps could be constructed of various layers of clay, soil, synthetic textiles, asphalt, or concrete. Controlling the flow of water through the contaminated soil at the northern industrial areas

with an engineered cap would prevent further contaminant loading from soil to the groundwater, worker exposure to the contaminated soil, and surface runoff of contaminants. A cap would also eliminate ecological exposures to the contaminated soil.

Prior to construction of a cap, geotechnical surveys would be conducted to evaluate soil properties at the site. Staging areas would be constructed, and vegetation would be cleared from the surface of the site. Fill material would be added to the site to create a foundation and level the surface. The cap components would then be installed. The cap could be constructed utilizing synthetic and/or earthen materials for the impermeable layers of the cap. This type of cap would create a hydraulic barrier above the contaminated soil and prevent further infiltration by blocking precipitation and draining it away from the site.

Initial Screening - A cap constructed with appropriate construction quality control, quality assurance, field testing, and field sampling of materials would reduce or eliminate contaminant mobility, although toxicity and volume would remain unchanged. Infiltration of rainwater through the contaminated soil would be eliminated, and contaminant loading to groundwater would be reduced. This option would effectively isolate the contaminated soil from the surrounding surface environment, eliminate potential human exposures with source material, and reduce or eliminate further contaminant loading of groundwater. Construction of a cap would be relatively easy to implement as long as it is constructed in an open area. Materials and equipment for cap construction are generally available. However, there are many small areas of explosives contamination at each of the northern industrial areas and it may be costly and difficult to install an engineered cap at each location. Also, cap construction may interfere with activities performed around the northern industrial areas. Because a cap would prevent contaminant loading to the groundwater, worker exposure, and surface runoff, it is retained for further consideration.

4.2.3.2 Soil Cover. Description - Covering areas of contaminated soil with clean soil would effectively achieve isolation of contaminants from the surface environment. Implementation of this option would require clearing existing vegetation, placing clean fill of dirt and topsoil, and replanting the area to prevent erosion.

Initial Screening - Although this method would not prevent infiltration through contaminated soil (except to the extent that the clean soil would be of lower permeability than the surface soil), it would prevent direct contact with the explosives-contaminated soil. This technique would be a relatively simple, low cost option to reduce or eliminate potential human exposures to the contaminants in the surface soil. Because this option would not prevent leaching of the contaminants to groundwater, it is eliminated from further consideration.

4.2.4 Soil Removal/Excavation

Description - Excavation of soil contaminated with explosives compounds at levels greater than 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds would remove the soil in the northern industrial areas that is above the risk-based remedial action objective. Removal of the contaminated soil would prevent worker exposure to the contaminated soil and protect groundwater quality. Excavation could be performed with a backhoe, dragline, or other heavy earthmoving equipment. The sandy material at MAAP would most likely require support or stabilization at deeper depths to prevent wall collapse. This technology would be used in conjunction with an on-site or off-site soil treatment method. Soil sampling would be performed to determine the area and depth of contaminated soil to be excavated for treatment, and to verify that the contaminated soil has been removed to below the remedial action objectives.

During excavation, contaminated particulates may be generated and dispersed into the atmosphere. Air monitoring during remediation actions would be conducted to measure releases of

contaminated particulates. An air monitoring program, including the regular use of a particulate counter, would provide a means of determining when additional dust controls are required.

Initial Screening - This technology would effectively remove contaminated soil around the northern industrial areas. Shoring or sloping may be required for excavation depths below 5 feet in accordance with OSHA requirements. Slope ratios of 2 (horizontal) to 1 (vertical) may be implemented as a conservative estimate to maintain stability. Soil may be excavated in six- to twenty-four inch lifts, and soil sampling would be conducted after each lift to ascertain the level of explosives compounds remaining in the soil. The large number of excavation points would pose a challenge for implementation. Proper disposal or treatment of the contaminated source materials would be implemented in order to reduce or eliminate the volume, mobility, or toxicity of the contaminants. Windblown emissions of contaminated dusts and transport of contamination in surface runoff would be controlled using water spray or plastic sheeting to minimize the generation and emission of airborne particulates. Silt fences, trenches, and other structures could be constructed to prevent surface runoff and erosion of contaminated soil. Appropriate levels of personal protective equipment would be used to minimize worker exposure to airborne contaminants. Excavation is retained for further consideration in the alternatives assembly.

4.2.5 Ex-Situ Soil Treatment

Soil treatment methods were evaluated based on the ability of each technology to treat explosives compounds. Mobile treatment units or semi-permanent units may be constructed on site in order to implement the thermal, biological, physical, and/or chemical treatment technologies. These technologies would be used to treat contaminated soil after excavation. In-situ technologies are considered in Section 4.2.6, and disposal options for treatment residuals are discussed in Section 4.2.8.

4.2.5.1 Thermal Treatment. Thermal treatment processes (USEPA, 1988b; USEPA, 1990b) use a controlled atmosphere to destroy or to detoxify hazardous wastes. Contaminants are converted to carbon dioxide, water, and other combustion products when burned with excess oxygen. This technology type is capable of complete destruction of contaminants, as well as significant volume reduction, detoxification, and energy recovery. High concentrations of contaminants such as explosives compounds may cause a safety hazard, but this would not be a concern for contaminated soil from the northern industrial areas. Studies conducted by USAEC indicate that sediments containing explosives concentrations similar to those detected in the soil at MAAP can be fed directly into the primary combustion chamber of an incinerator without exceeding acceptable safety considerations (USAEC, 1984). High metals concentrations, including naturally-occurring metals, may cause adverse effects in some systems. Combustion products of some heavy metals and volatile metals such as mercury are not always removed from incinerator off-gases by air pollution control devices. However, the levels of metals detected during the soil sampling at MAAP are low enough that these problems would not be encountered (USAEC, 1991a). Monitoring for releases of airborne contaminants from treatment processes (i.e. incinerator stack emissions) could be conducted to ensure safe operation and adequate pollution control for such systems. Thermal treatment processes that are potentially applicable for treating contaminated soil are described and screened below.

Rotary Kiln Incineration. Description - Rotary kilns are refractory-lined cylinders that are slightly inclined from horizontal. Wastes and auxiliary fuel enter the incinerator at the high end, and are combusted with excess oxygen. The combustion chamber rotates as wastes are combusted and move to the low end of the unit. Mixing of wastes occurs through rotation, and this mixing allows complete combustion of waste materials. Waste materials are transformed into ash and combustion gases, including carbon dioxide and water. Rotary kilns also have a secondary combustion chamber to ensure complete combustion of gases. Off-gases are treated to remove acid gases and particulates, and ash (decontaminated soil) is removed at the lower end of the unit. Residuals from this process include

decontaminated soil from the combustion chamber, particulates and scrubber solution from the air pollution control device, and stack gases. Scrubber solutions are generally recycled.

Initial Screening - This technology has been effectively demonstrated for many hazardous waste applications and for treating explosives-contaminated soil. This technology has been used for remediation of explosives-contaminated soil at Savanna Army Depot Activity (SADA), Savanna, Illinois, at Cornhusker Army Ammunition Plant, Grand Island, Nebraska, and at Louisiana Army Ammunition Plant (LAAP), and is currently being utilized at Alabama Army Ammunition Plant. In a pilot-scale treatability study, DREs of greater than 99.99 percent were achieved using a rotary kiln incinerator (USAEC, 1984). This technology is widely available as fixed, transportable, and mobile units. Further investigation would be performed to accurately characterize the physical and chemical parameters of the soil to determine applicability of rotary kiln incineration, because the size and shape of the particles making up the waste could affect the performance of this process. Because it is a proven technology for similar wastes, rotary kiln incineration is retained for further consideration.

Fluidized Bed Incineration. Description - A fluidized bed incinerator consists of a refractory-lined combustion vessel with a bed of inert material at the bottom. When used to treat contaminated soil, the soil is the bed material. Waste materials can be directly injected into the bed or onto the bed surface. While operating, air is forced upward through the bed, fluidizing the bed and material to a minimum critical velocity. Fluidization in the vessel creates a turbulent atmosphere that can achieve complete combustion. The heating value of the wastes and auxiliary fuel (such as natural gas) supports combustion. A secondary combustion chamber exists to provide adequate retention time for the destruction of VOCs. Combustion gases are emitted from the secondary chamber and treated for acid gases and particulate constituents. Treatment residuals include decontaminated soil or ash, treated combustion gases, and residues from air pollution control devices.

Initial Screening - This technology has the potential to be effective in treating the explosives compounds detected in soil samples from the northern industrial areas. Efficient contaminant destruction may be achieved due to the high mixing energies which aid the combustion process. Transportable fluidized bed incinerators are commercially available. However, certain soil characteristics such as grain size and moisture content may affect the effectiveness of this technology, and implementability of fluidized bed incineration is uncertain. In addition, this technology has not been demonstrated on explosives-contaminated soil. Further study would be required to evaluate the effectiveness of this technology for treating soil from the northern industrial areas. Because of the uncertainties in treating explosives-contaminated soil with fluidized bed incineration, this technology is eliminated from further consideration.

Infrared Incineration. Description - Infrared incineration takes place in a primary combustion chamber made of carbon steel and lined with refractory materials. Wastes are fed into the chamber on a conveyor belt able to withstand high temperatures. The wastes pass beneath a series of silicon carbide heating elements, which are electrically powered and emit infrared energy. Processed material is discharged from the furnace, while exhaust gases pass into a secondary combustion chamber which is similar in construction to the primary chamber. Auxiliary fuel or additional infrared heating elements are used to ignite remaining combustible gases in the secondary chamber. The entire unit can be operated in an oxidizing, reducing, or pyrolytic atmosphere. Wastes generated by this process are decontaminated soil (ash), off-gases, and air pollution control device residuals.

Initial Screening - This process has been demonstrated to treat CERCLA wastes containing halogenated and nonhalogenated organics, including polychlorinated biphenyls (PCBs), on a commercial scale. Commercial infrared systems are available, but on a more limited scale than rotary kilns. Transportable infrared furnace units are commercially available. However, this technology has not been demonstrated on explosives-contaminated soil. Further study would be required to evaluate the effectiveness of this technology in treating soil from the northern industrial areas. Because of the

uncertainties in treating explosives-contaminated soil with infrared incineration, this technology is eliminated from further consideration.

Pyrolytic Incineration. Description - Pyrolysis units are batch treatment systems which treat wastes in a controlled oxygen atmosphere. These units slowly volatilize organics at relatively low temperatures in a two-stage process. In the first stage, wastes are combusted under starved air conditions, causing most of the volatile organics to be destroyed pyrolytically. Required heat typically is provided by oxidation of carbon compounds in the wastes. The waste gases from the primary chamber pass to a secondary chamber, where combustion of gases occurs with excess oxygen to ensure complete combustion. Final off-gases are usually minimal, and the low turbulence in the primary chamber causes low particulate entrainment.

Initial Screening - This process is commercially available and has the potential to be effective on organic wastes, although it has not been sufficiently demonstrated on CERCLA wastes. High residence times are required to ensure complete pyrolysis of organics; therefore, these systems have lower throughput than other incineration systems. Because of the large volume of wastes that may need to be treated, this system may be inappropriate for contaminated soil from the northern industrial areas. Applicability of the starved air system to destroy explosives compounds is unknown. For these reasons, this technology is eliminated from further consideration in the alternatives assembly.

Vitrification. Description - Hazardous materials are immobilized by incorporation into a glass-like material or are destroyed by the high temperatures needed for the vitrification process. Wastes are heated to temperatures high enough to melt the waste substrate and transform it into a solid mass upon cooling. High temperatures also destroy hazardous constituents and reduce organic materials to carbon, carbon monoxide, and hydrogen. Gaseous emissions are relatively low, and the resultant mass is stable and immobilizes inorganics such as heavy metals. The reaction chamber has two sections, both of which utilize electric heating systems. The lower section contains a molten zone for melts of metals and siliceous components of the waste, and the upper chamber treats off-gases. Residues from the process are molten glass containing bound metals, some off-gases, and air pollution control device residuals.

Initial Screening - This process could treat the contaminants of concern in the soil from the northern industrial areas. Moisture content is limited to 25% water by weight for effective implementation of this process; soil from the northern industrial areas would satisfy this requirement. Although this process has the potential to effectively remove organics and to immobilize heavy metals, it has not been adequately demonstrated for explosives compounds. Availability of the system is limited in this country. For these reasons, this process option is eliminated from further consideration.

4.2.5.2 Biological Treatment. Biological treatment utilizes indigenous or introduced microorganisms to biologically degrade organic constituents. During biodegradation, contaminants are broken down and heat is generated by microbial metabolism. Bacteria, fungi, and yeasts can degrade contaminants in aerobic or anaerobic environments. In aerobic conditions, organic contaminants are decomposed to carbon dioxide, water, and cell protein. Under anaerobic conditions, byproducts are methane, carbon dioxide, and cell protein. Solid-phase (composting) and slurry-phase (aerobic and anaerobic bioslurry) treatment processes have been developed for a wide range of organic contaminants.

Composting. Description - In composting systems, waste materials are mixed with bulking agents and amendments such as wood chips, straw, or manure. Amendments provide nutrients for the microorganisms, and bulking agents alter the physical characteristics of the compost material to make it more suitable for biodegradation. The compost mixture is then placed in a controlled environment where temperature, nutrients, and oxygen could be adjusted, and gaseous emissions and leachate could be collected and treated. The simplest composting method is static pile composting, with compost material placed in a pile and allowed to self-heat. Compost piles could be formed into long windrows

where they are mixed using a mechanical turner. Controlled static pile composting integrates an aeration and heat removal system by placing perforated pipes under the compost pile. Air could be drawn or forced through the piping to aerate the pile and control heating. The highest level of composting technology is mechanically agitated in-vessel (MAIV) composting, which consists of an automated material handling system that feeds soil into an enclosed vessel where the soil is composted. MAIV composting decreases the time required for biodegradation by carefully controlling the composting environment and is a continuous treatment process which includes materials handling, aeration, and temperature control systems (USAEC, 1988b; USAEC, 1991b; USEPA, 1990b; USAEC, 1993b).

Initial Screening - Equipment used for materials handling, aeration, and waste treatment are readily available, and bulking agents and nutrients could easily be obtained. In field-scale demonstrations, composting has been proven to be effective in reducing toxicity of explosives-contaminated soil (USAEC, 1988b; USAEC, 1991b; USAEC, 1993b). In tests performed at LAAP and at Umatilla Army Depot Activity (UMDA), measurable concentrations of 2,4,6-TNT, RDX, and HMX were reduced by up to 99%. Physical characteristics of the soil were similar to those found at the northern industrial areas of MAAP, with the exception of total explosives concentration. Total explosives concentration in soil that was treated were generally much higher than the concentrations found in soil at northern industrial areas of MAAP. At UMDA, the sum of 2,4,6-TNT and RDX in soil initially averaged about 6,100 μg/g (USAEC, 1992a), and optimization studies indicated that a soil to be composted should ideally contain a minimum of 10,000 μg/g of total explosives.

Tests at UMDA resulted in final concentrations of 2,4,6-TNT and RDX of 1 to 18 μg/g (USAEC, 1992a; USAEC, 1993b), although further degradation could occur with a additional composting time. Soil is generally added as 10 to 30 percent of the compost mixture, which means that before biodegradation begins, explosives concentrations are one-tenth to one-third of the initial concentrations in soil. Assuming an initial explosives concentration of 1,000 μg/g in the soil from the northern industrial areas, the compost mixture would have a total explosives concentration of 100 to 300 μg/g. Dilution of explosives compounds upon addition of bulking agents and amendments could reduce optimal biomass/contaminant contact.

Other studies have determined that 2,4,6-TNT undergoes biotransformation rather than biodegradation in composts, soil, and biological waste treatment systems (Burrows, et al., 1989). These biotransformation processes may form compounds with unknown toxicity, although these compounds have been shown to be bound to organic matter. Short-term tests have shown reduction in toxicity and mutagenicity of composted soil, but long-term effects and identification of many of the explosives biotransformation products are unknown. Toxicity reduction appeared to be greater using unaerated composting as opposed to aerated composting (USAEC, 1993b). In addition, compost compaction studies performed at UMDA indicated a 40 to 60 percent increase in the volume of composted soil as compared to the initial in-place soil volume (USAEC, 1993c). More studies would be needed to fully evaluate the operating parameters for soil composting at the northern industrial areas. Because composting is a relatively proven technology which could reduce the explosives levels and toxicity of explosives-contaminated soil, it is retained for further consideration.

Aerobic Bioslurry. Description - Aerobic bioslurry reactors are batch treatment systems which reduce biodegradable organic contaminants in a controlled environment. Aerobic bioslurry treatment enhances the degradation of organic contaminants using microorganisms indigenous to the soil. These systems are different from other biological treatment technologies because the systems are capable of increasing the degradation rate of contaminants by increasing the availability of contaminants, cometabolites, electron acceptors, nutrients and other additives to the microbial consortia. This is accomplished by completely mixing the soil in a water slurry (typically at 40 percent solids); thereby reducing mass transfer limitations associated with biotreatment of contaminated soil. Aerobic bioslurry systems maintain oxygen levels by diffusion of air or oxygen into the soil/water slurry. The result of these operational features is a biological system that is conducive to optimal microbial activity and increased

contaminant degradation rates (Zappi, et al., 1993). As opposed to composting, aerobic bioslurry is performed in a saturated environment which decreases the potential hazards due to fire and explosion during dry handling. In addition, small quantities of amendments and no bulking agents are required which eliminates the problem with increased soil volume that occurs during composting.

Initial Screening - Bench-scale tests with aerobic bioslurry systems have demonstrated effective treatment of soil contaminated with 2,4,6-TNT (Zappi, et al., 1993). Biological degradation of the 2,4,6-TNT included partial mineralization of the 2,4,6-TNT along with the formation of biotransformation byproducts similar to those produced during composting. More bench-scale and pilot-test data would be needed to fully evaluate the overall performance of aerobic bioslurry reactors. This process is not readily available and may require as much as 2 years of development before full-scale treatment can begin; however, because aerobic bioslurry is capable of mineralizing explosives compounds in soil and reducing its toxicity, it is retained for further consideration.

Anaerobic Bioslurry. Description - Anaerobic bioslurry reactors are similar to aerobic bioslurry reactors in that the biodegradation of the soil/water mixture is performed in a controlled environment, but the anaerobic process is performed in the absence of oxygen. In the anaerobic environment, microorganisms biodegrade explosives compounds and their associated biodegradation products into p-cresol, methane, and carbon dioxide. As with the aerobic bioslurry system, the environmental parameters such as pH, temperature and nutrients could be monitored and optimized in the batch process to increase the biodegradation rate of organic contaminants. Anaerobic bioslurry reactors are designed to prevent oxygen from entering the reactor while allowing methane and carbon dioxide to vent to the outside atmosphere.

Initial Screening - Based on bench-scale data, the manufacturers of anaerobic bioslurry reactors have demonstrated up to 80 percent mineralization of explosives compounds. In a field demonstration under the USEPA Superfund Innovative Technology Evaluation (SITE) demonstration program, 2,4,6-TNT, HMX, and RDX were mineralized with low levels of biodegradation intermediates (4-amino-2,6-dinitrotoluene, 2,4-diamino-6-nitrotoluene, and p-cresol) remaining after treatment. During this study, 2,4,6-TNT levels dropped from over 1000 μg/g to below method detection limits. Increasing levels of carbon dioxide were observed during this study, while the explosives levels were decreasing, which may have been associated with the mineralization of explosives compounds. More bench-scale and pilot-test data would be needed to fully evaluate the overall performance of anaerobic bioslurry reactors. This process is not readily available and may require as much as 2 years of development before full-scale treatment can begin; however, because anaerobic bioslurry is capable of mineralizing explosives compounds in soil and reducing soil toxicity, it is retained for further consideration.

4.2.5.3 Physical/Chemical Treatment. Physical treatment processes separate hazardous constituents from the soil matrix. Chemical treatment processes chemically alter the structure of hazardous constituents to make a less hazardous form of the contaminant and produce a waste residue where constituents may be less difficult to treat. Solvent extraction, soil washing, and stabilization/solidification are discussed in this section (USEPA, 1988b; USEPA, 1990a).

Solvent Extraction. Description - This process makes use of a solvent to separate contaminants from soil particles by partitioning the contaminants from the soil to the solvent. Solvents are mixed with contaminated soil at low temperatures and a high pH, and then centrifuged or filtered to separate the extracted materials from the liquid-phase. Solids are then dried to recover the solvent, which may be recycled. The resulting liquid phase solution is heated, which breaks emulsions and separates the organic and aqueous phases. This two-phase solution is then decanted, removing the organic/solvent-rich top fraction. Both phases require further treatment in separate stripping columns and possibly distillation for further refinement. Pretreatment is commonly required before solvent addition.

Initial Screening - This process option has been successful in the treatment of PCB-contaminated soil, and has the potential to successfully remove other organic constituents. In order to be cost-effective, acceptable wastes must contain greater than 200 ppm organics, which is not the case for the explosives-contaminated soil from the northern industrial areas. Solvent extraction using acetone as the solvent has been shown to be technically feasible for treating explosives-contaminated soil, but this process is unsafe (Sisk, 1992). To make the process cost-effective, the acetone/explosives extract must be heated to recover the acetone, which could cause detonation. Other solvents such as nitrobenzene could also be used, but similar problems would most likely be encountered. Because of these hazards, solvent extraction is eliminated from further consideration.

Soil Washing. Description - Explosives compounds may be adsorbed on soil particles. Contaminants are "washed" from soil using a liquid medium such as water. Organic solvents, water/chelating agents, water/surfactants, acids, and bases may also be used to extract contaminants. Soil is fed through the system, passed through a soil scrubber, and sprayed with washing fluid. Soil washing separates larger sand particles from clays. The clay fraction, onto which most contaminants are adsorbed, is treated in a countercurrent chemical extractor and is dewatered. The washing fluid is eventually treated by conventional wastewater treatment systems.

Initial Screening - This process has been demonstrated to effectively treat soil contaminated with VOCs. Bench-scale tests on soil with nitrated aromatic contaminants have shown soil washing to be effective (USEPA, 1990a), but effectiveness is largely dependent on site-specific soil properties. This process is most suitable for sites where contaminants are adsorbed to clay particles, which is not the case at the northern industrial areas (contaminants are generally associated with silty sand). However, the effectiveness of soil washing for explosives-contaminated soil is unknown and the ability to formulate a suitable washing fluid (i.e. result in adequate efficiency) may be difficult. Washing fluids may also be difficult to recover, recycle, or treat, which would increase the cost of the process. This process is not readily available. For these reasons, soil washing is eliminated from further consideration.

Stabilization/Solidification. Description - Stabilization converts a waste to a more chemically or physically stable form, utilizing a chemical reaction to immobilize a toxic compound. Solidification processes add binding agents to a waste, and the product is a solid material that is resistant to leaching. Binding agents could include cement, pozzolan, silicates, thermoplastics, and organic polymers. The goal of these processes is to reduce the mobility of contaminants by reducing the ability for contaminants to leach from contaminated soil. A stabilization/solidification system generally consists of a materials handling system, a mixing unit, a curing area, and an area for final disposal.

Initial Screening - This treatment technique has been very effective in stabilizing inorganics, but less effective in immobilizing organics. Halides, cyanides, semivolatile organics, polynuclear aromatic hydrocarbons (PAHs), and soluble salts of manganese, tin, zinc, copper, and lead may interfere with the bonding of waste materials. Stabilization/solidification is largely ineffective on organic compounds and has not been proven effective for soil contaminated with explosives compounds. Although the soil is treated to reduce leaching, the explosives compounds themselves would not be transformed or destroyed, and tests have shown that the stabilized mass could release explosives compounds at a rate similar to that of untreated soil (Sisk, 1993). This process option would provide little reduction in mobility of contaminants, and does not reduce contaminant toxicity or volume. For these reasons, this technology is eliminated from further consideration.

4.2.6 In-Situ Soil Treatment

In-situ treatment offers the advantage of treating soil without the prerequisite of excavation. Methods which apply to surface soil, subsurface soil, or to both have been developed. However, many of these methods are not proven, and effectiveness is highly dependent on site-specific characteristics.

4.2.6.1 Biomining. Description - Biomining utilizes various plants to extract contaminants from near-surface soil. Studies have shown that some plants preferentially uptake certain compounds and store them in plant tissues. Explosives compounds have been removed from contaminated soil by bush beans, wheat, blando brome, and jimson weed (Cataldo et al., 1989; Cataldo et al., 1990; Fialka, 1992). After appropriate site preparation, seeds or seedlings are planted and allowed to grow. Mature plants are disposed of by incineration or some other appropriate method.

Initial Screening - Although controlled experiments have demonstrated plant uptake of explosives compounds, applicability for the surface soil at the northern industrial areas would need to be proven. This method would only treat near-surface soil in the surface soil root zone. The plant type that could most efficiently extract contaminants would need to be determined. In one study, RDX concentrations in soil have been reduced by 10 to 55% with various plants (Cataldo et al., 1990). The materials necessary for implementing this process would be relatively easy to obtain. The primary drawback of this technology is the inability to treat soil that is deeper than the root zone. Plant roots generally penetrate several inches below the ground surface; however, soil at the northern industrial areas is estimated to contain explosives compounds above the risk-based remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds to a maximum depth of 10 feet below the ground surface at the northern industrial areas. Disposal of contaminated plants, either by composting or incineration, adds significant cost to the process. Therefore, biomining is eliminated from further consideration in the alternatives assembly.

4.2.6.2 In-Situ or Intrinsic Biodegradation. Description - Biodegradation is a natural process in which contaminants are degraded by indigenous soil microorganisms. In-situ or intrinsic biodegradation offers the advantage of avoiding excavation while treating the contaminated soil. Intrinsic biodegradation has been demonstrated to be effective for treatment of hydrocarbons and other petroleum constituents, chlorinated solvents, and wood preserving wastes such as cresols and phenols. The natural processes may occur under either aerobic or anaerobic conditions. The acceptability of intrinsic biodegradation as a remediation process depends on the presence of three factors: (1) demonstrated reductions in mass of contaminants in the soil; (2) demonstrated presence of biodegradation products and proper conditions for their formation; and (3) laboratory/pilot-scale demonstrations of the process under controlled conditions.

Aerobic conditions allow destruction of certain contaminants faster than under anaerobic conditions. Aerobic conditions could be enhanced with an in-situ process by injecting air or hydrogen peroxide into the contaminated soil zone through injection wells. Biological activity of indigenous microorganisms could also be enhanced by injecting nutrients into the contaminated zone.

Initial Screening - It is well known that 2,4,6-TNT degrades in soil, most likely by acting as an electron acceptor for indigenous microorganisms during metabolism of other organic compounds. In-situ or intrinsic biodegradation potentially could treat the explosives compounds detected in the soil at the northern industrial areas. Enhanced in-situ biodegradation has traditionally been used for gasoline and diesel contaminants, but its performance on contaminants such as explosives compounds is unknown. Based on the discussion of ex-situ biological treatment processes in Section 4.2.5.2, the toxicity reduction of explosives-contaminated soil treated under unaerated conditions appear to be greater than under aerated conditions; therefore, the addition of oxygen may not be an attractive option.

Intrinsic biodegradation is not subject to control, and the proper conditions of pH, conductivity, and nutrient availability would be necessary for this process to be effective. Monitoring would need to be performed to determine if these conditions exist and if they could be maintained. Extensive pilot-scale research would be necessary to ensure that more harmful byproducts are not produced and introduced to the soil or groundwater as a result of the biodegradation of explosives compounds. Because intrinsic

biodegradation may be occurring and could be enhanced by in-situ processes, it is retained for further consideration.

4.2.6.3 In-Situ Soil Flushing. Description - This process uses an appropriate washing solution to mobilize organic contaminants from soil. The area to be treated would be flooded with washing solution, which percolates downward through the contaminated zone. An aggressive approach may be taken by using ponds or sprinklers to flush the contaminated zone. Contaminants are mobilized by solubilization, formation of emulsions, or by chemical reaction. The solution could be captured by extraction wells after leaching into the aquifer. The washing solution could be treated and/or recycled. The solution must be captured to prevent further contamination of the aquifer or surrounding, uncontaminated areas. Groundwater extracted from the aquifer could then be pumped, treated, and reapplied to the surface of the contaminated zone.

Initial Screening - This technology has the potential to treat most of the organic contaminants detected in the soil at the northern industrial areas, but would need to be implemented along with a remediation system for groundwater. However, there are a large number of potential problems associated with implementing this remedial option at the site. First, use of in-situ flushing would affect the local hydrology (by causing a groundwater "mound" to form under the soil being treated) and would change the existing concentrations of contaminants in the shallow groundwater zone (by mixing contaminated leachate with the existing groundwater, which may be contaminated). Secondly, the groundwater mound expected to form under the flushing system would cause lateral movement of contaminants and spread the area of contaminated groundwater. The thickness of the vadose zone (approximately 40 to 90 feet depending on the location of the load line) makes it difficult to predict the transit time from the surface to the aquifer and the resulting contaminant concentrations in the leachate. Finally, the aquifer underlying MAAP is thick (greater than 200 feet), laterally extensive, and highly transmissive. It is currently being used as a drinking water source by the facility and off-site residents. The flushing process may cause further contamination of this resource. For these reasons, soil flushing is eliminated from further consideration in the alternatives assembly.

4.2.6.4 In-Situ Vitrification (ISV). Description - In the ISV process, contaminated soil is melted in place, binding the contaminants in a glassy, resistant, solid matrix form. Electrodes are inserted into the soil and conductive material is placed between them to aid the electrical conductance. Electrical current is transferred to the surrounding soil and the soil is melted, incorporating the nonvolatile contaminants. Organic components are pyrolyzed, and the byproducts travel to the vitrified surface where they combust. A hood is placed over the contaminated area in order to trap any volatiles which may be generated. Inorganics are trapped within the vitrified mass.

Initial Screening - This process has the potential to treat the contaminants of concern within the soil at the northern industrial areas. However, the presence of shallow groundwater or perched water may cause complications in this system. Additionally, applying high electrical currents to the soil and the presence of molten soil may be extremely dangerous around active load lines within the northern industrial areas. Although this process has the potential to effectively remove organics and to immobilize heavy metals, it has not been adequately demonstrated for explosives compounds. This process has not been widely used on this scale, and its practical application is not well known. For these reasons, ISV is eliminated from further consideration.

4.2.6.5 In-Situ Stabilization/Solidification. Description - In-situ methods of stabilization and solidification attempt to achieve the same objectives as ex-situ stabilization and solidification, without excavating the soil to be treated. In-situ application methods include surface application of liquid binding agents for shallow treatment; mixing with backhoes, draglines, or other earthmoving equipment; or the use of injection/mixing methods. Injection/mixing methods use hollow augers to bore into the contaminated soil and inject binding agents. The soil is mixed by rotating the auger, which has mixing

blades or fins attached. Treated soil forms a solid column and treated columns are overlapped to ensure complete soil treatment.

Initial Screening - In-situ methods are available to apply and mix binding agents into soil up to a depth of approximately 50 feet, which would be applicable at the northern industrial areas. This treatment technique has been very effective in stabilizing inorganics, but ineffective for binding organic compounds. For the same reasons as discussed for ex-situ stabilization/solidification, this treatment option is eliminated from further consideration.

4.2.7 Off-Site Treatment

4.2.7.1 Off-Site Incineration. Description - Source materials excavated from the northern industrial areas could be incinerated off site. Excavated materials would be transported and treated at an appropriate facility. Analytical data indicating the constituency of the waste would be required upon delivery of the waste.

Initial Screening - Incineration would permanently reduce the toxicity, volume and mobility of contaminants. However, incineration at an off-site facility would be very costly because permitting and facility fees would be very expensive. The nearest off-site incinerator accepting explosives-contaminated soil is located in Calvert City, Kentucky, which is approximately 200 miles from Milan, Tennessee. The estimated price for incineration of the contaminated soil is approximately $1,700 per ton. Transportation costs for hazardous waste (assuming, in the worst case, that some of the soil is a hazardous waste) are approximately $30 per ton for a 400-mile round trip. Although off-site incineration would permanently reduce the toxicity, volume and mobility of contaminants, the costs incurred are not competitive for larger quantities. Therefore, this option is eliminated from further consideration, unless it is found that only small quantities of soil need to be excavated and treated.

4.2.8 Disposal

Options for disposal of contaminated soil and/or treatment residuals would be necessary only in cases where source excavation was implemented. As discussed in Section 3.4.1, the contaminated soil from the northern industrial areas is not classified as a RCRA-listed hazardous waste, and the contaminated soil does not contain sufficient quantities of explosives compounds to be classified as reactive hazardous waste. However, the explosives compounds within the contaminated soil from the northern industrial areas may generate a toxic leachate. Because the contaminated soil would be considered hazardous through failing TCLP, a treatment step would be needed prior to disposal. If the treated soil is not a hazardous waste, but contains low levels of explosives compounds or associated treatment residuals, it would be disposed as a solid waste. However, if the soil was treated to the extent that regulators would consider the treated soil uncontaminated, the soil could be backfilled into the excavated space. Disposal options apply to source materials which have been treated or not treated.

4.2.8.1 On-Site Landfill. Description - As previously mentioned, the treated soil from the northern industrial areas may contain low levels of explosives compounds and treatment residuals. Therefore, it may be appropriate to design an on-site landfill for disposal of treated soil according to either RCRA Subtitle C or Subtitle D guidelines.

Initial Screening - The use of on-site landfills would require meeting all applicable and substantive requirements of either Subtitle D or Subtitle C of 40 CFR 210-220 concerning the siting, design, construction, closure, and post-closure care of facilities. However, the potential liability associated with off-site transport is eliminated. Also, under the LDRs, untreated hazardous wastes may not be land-disposed. If the treated soil is not considered a hazardous waste, but contains low levels of explosives compounds or associated treatment residues, it may be disposed in a Subtitle D solid waste landfill.

Because soil treated using biological treatment processes may contain explosives compounds or biodegradation byproducts, on-site landfilling is retained for further consideration.

4.2.8.2 Backfill Treated Soil. Description - Source materials could be backfilled into the excavated space after treatment, provided that it is treated to the extent that the regulators would consider the treated soil uncontaminated rather than a hazardous or solid waste. This option could be easily implemented subsequent to on-site treatment of contaminated soil. Analytical data of the treated soil would be necessary to ensure compliance with environmental regulations.

Initial Screening - This option would provide an easily implementable and cost effective method for disposal of treated soil. Finding an alternative disposal site for treated soil and obtaining clean backfill from another source and hauling it to the site would be avoided. However, large quantities of clean soil are available at MAAP. Chemical analysis of treated soil would be required before backfilling to verify that the treated soil is not a solid or hazardous waste. This option is retained for further consideration in the alternatives assembly.

4.2.8.3 Off-Site Landfill. Description - An off-site solid waste (RCRA Subtitle D) or hazardous waste (RCRA Subtitle C) facility could be utilized for soil, depending on the nature of the excavated source materials. Analytical data collected from the waste would be required upon delivery of the waste.

Initial Screening - This process option could effectively immobilize the waste materials, but would be difficult to implement and costly. Explosives-contaminated soil would have an associated leachable toxicity, therefore, the soil would be disposed as a hazardous waste. The nearest hazardous waste landfill is in Alabama, so the cost of transportation would be excessive for the potentially large quantity of soil to be disposed. Transportation required for off-site disposal increases the short-term risks of an accident and subsequent public exposures. Off-site disposal would also raise long-term liability issues. Therefore, this option is eliminated from further consideration.

4.3 SUMMARY OF REMEDIAL TECHNOLOGY SCREENING

The remedial technologies and process options which have been evaluated are presented in Figure 4-1, along with the results of initial implementability, effectiveness, and cost screening. Each of the remedial technologies and process options which were retained for consideration could be implemented individually or combined using several process options.

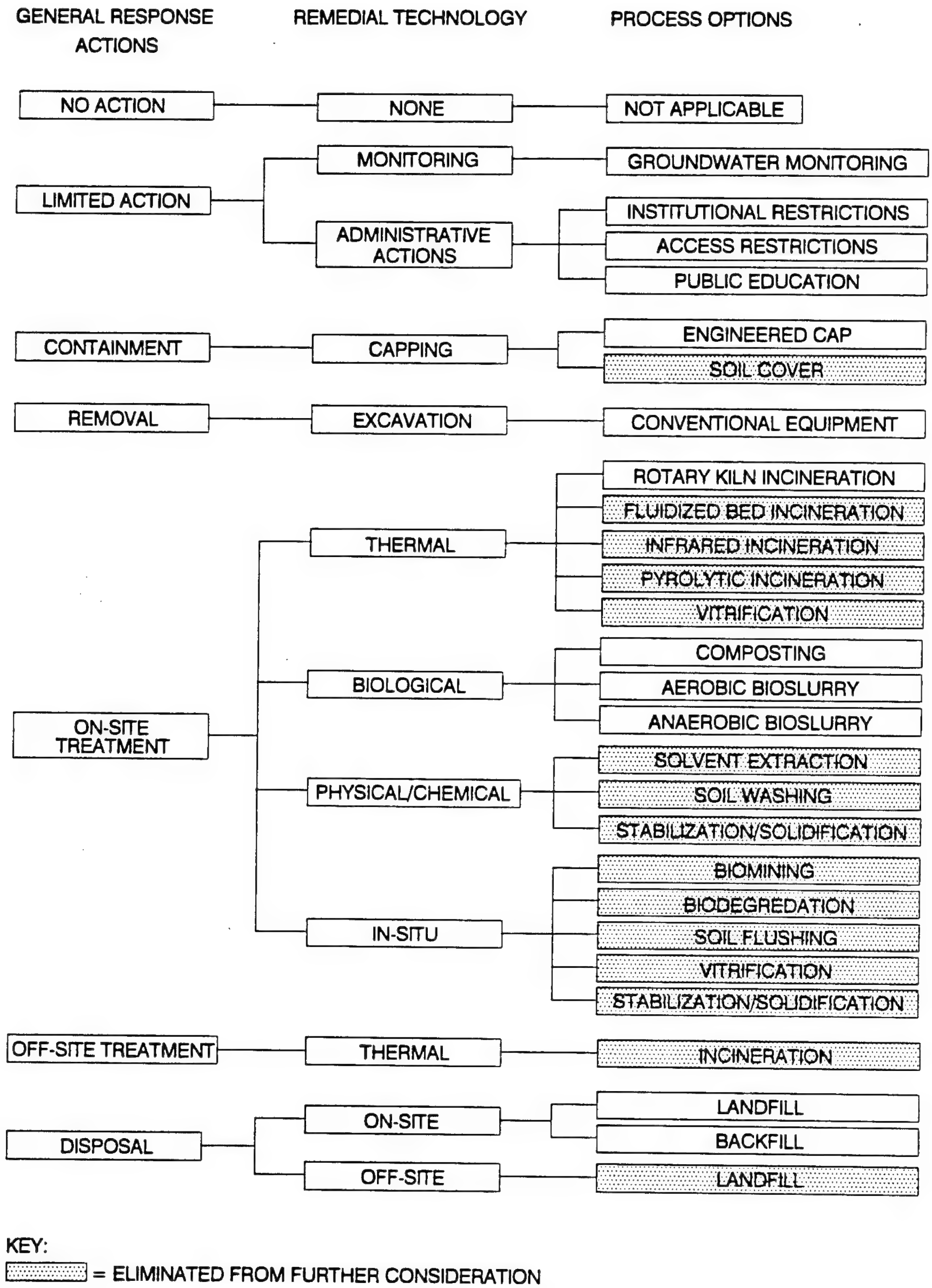


Figure 4-1
Remedial Technologies Retained for the Alternatives Assembly

5.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES FOR SOIL

This section develops remedial alternatives for the site which reduce human health risks associated with contaminated soil around the northern industrial areas. Development of remedial alternatives must conform to the requirements identified in CERCLA as amended and, to the maximum extent possible, the NCP. Section 300.68 of the NCP specifically refers to ARARs in the development of alternatives. CERCLA section 121(d) requires that Superfund remedial actions attain ARARs or other Federal statutes unless specific waivers are granted. Superfund remedial actions must also attain State requirements that are more stringent than Federal requirements to the extent that they are also ARARs and are identified to the USEPA in a timely manner.

CERCLA Section 121(b) identifies the following statutory preferences when developing and evaluating remedial alternatives:

- Remedial actions involving treatment which permanently and significantly reduce the volume, toxicity, or mobility of the contaminants or hazardous substances are preferred over remedial actions not involving such treatment;

- Off-site transport and disposal of hazardous substances or contaminated materials without treatment is considered to be the least favored remedial action alternative when practical treatment technologies are available; and

- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies shall be assessed.

Based on these statutory preferences, remedial alternatives were developed combining one or more general response actions in order to satisfy the following criteria:

- Alternatives were compared using the No Action alternative as a baseline;

- Remedial alternatives that are protective of human health and the environment;

- Remedial alternatives that attain chemical-specific ARARs and could be implemented consistently with location-specific and action-specific ARARs;

- Remedial alternatives that use permanent solutions and treatment technologies to the maximum extent possible; and

- Remedial alternatives that are capable of achieving a remedy in a cost-effective manner.

Technology types were screened in Section 4 based on three factors: implementability, to eliminate those technologies which are not feasible due to general site conditions such as the volume of soil or the capacity of the treatment process; effectiveness, to eliminate technologies which generally have not been proven effective in reducing the contaminants of concern at this site; and cost, to discard technologies which are very costly and do not offer advantages over other technologies. In this section, the screened technologies are assembled into remedial alternatives based on the above-listed criteria. Alternatives are incorporated into each of the following general response actions:

- No Action;
- Limited Action; and
- Excavation, On-Site Treatment, and Disposal.

Section 5.1 describes Alternative A: No Action, and Section 5.2 describes Alternative B: Limited Action. These two alternatives do not incorporate treatment components but provide a basis to which active treatment alternatives may be compared. The general response actions that were retained following technology screening have been combined into two general response actions to create alternatives capable of meeting the above preferences and criteria. Two on-site excavation, treatment, and disposal alternatives were developed to remove contaminated soil to below risk-based levels, treat the excavated soil to remove contamination (using thermal or biological processes), and dispose of the treated soil. The excavation, treatment, and disposal options would reduce direct exposure to the contaminants and protect the groundwater. A containment option was developed within each of the excavation, treatment, and disposal alternatives to cover explosives-contaminated soil in areas where excavation may be uneconomical or impractical (i.e. where the stability of a building foundation may be compromised by excavation). Section 5.3 discusses the two on-site excavation, treatment, and disposal alternatives.

5.1 ALTERNATIVE A: NO ACTION

The No Action alternative, Alternative A, has been developed to provide a basis for comparing active treatment alternatives. The NCP and CERCLA, as amended by SARA, require the evaluation of this alternative as a baseline for comparison of risk reduction achieved by each treatment alternative. The No Action alternative does not involve any remedial actions. Five-year reviews of site conditions are required by CERCLA because contamination remains at the site.

5.2 ALTERNATIVE B: LIMITED ACTION

The Limited Action alternative, Alternative B, has been developed to reduce the potential for public exposure to the contaminated media. The toxicity, mobility, or volume of contaminants would not be reduced. As described in Section 4, such measures would include institutional restrictions, access restrictions, public education programs, possible long-term environmental monitoring, and five-year reviews. This alternative would consist of continued maintenance of the existing fences around the northern industrial areas. These activities would be performed under a Memorandum of Agreement with USEPA Region IV and the Tennessee Department of Environment and Conservation (TDEC).

5.3 EXCAVATION WITH ON-SITE TREATMENT AND DISPOSAL

Excavation, storage, on-site treatment, and disposal is the third general response action. Incineration and biological treatment are the two on-site treatment alternatives developed under this general response action.

5.3.1 Alternative C: Excavation/Storage/Incineration/Backfill

The four components of this alternative are excavation, storage, on-site treatment, and backfilling of the treated soil. The excavated soil would be treated utilizing a mobile rotary kiln incinerator. Excavation could be performed using conventional construction equipment such as drag lines, backhoes, or other heavy earthmoving equipment. The following scenarios are evaluated in Section 6:

- Excavation of the soil from the northern industrial areas with concentrations of explosives compounds greater than 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds. Excavation would be performed to a maximum depth of 10 feet. The total volume excavated has been estimated to be approximately 22,200 cubic yards.

- Excavated soil would be stockpiled for treatment in a covered storage facility.

Rotary kiln incineration is proposed as the on-site treatment technology because it has been demonstrated to be effective and implementable on explosives-contaminated soil (USAEC, 1984; USAEC, 1992a). After the contaminated soil is incinerated, laboratory analyses of the treated soil would be performed to confirm the effectiveness of the treatment. Because incineration is expected to reduce the levels of explosives compounds to below analytical detection limits, the soil would be considered uncontaminated; therefore, the treated soil would be backfilled into the areas where the explosives-contaminated soil was excavated, covered with topsoil, and revegetated.

Containment of explosives-contaminated soil is proposed where excavation of the contaminated soil would be uneconomical or impractical. Large excavations in the vicinity of active load lines may be dangerous to workers within the areas. In some cases, excavation activities performed adjacent to large buildings could undermine the foundation of the building. With the containment option, the contaminated soil would be left in place and passive controls would be instituted to eliminate direct exposure to the contaminants in the soil and to protect groundwater quality. Containment measures such as an engineered cap would reduce direct exposure to the contaminated soil and protect the groundwater. The engineered cap would be designed to meet all Federal and State relevant and appropriate requirements which require a cap to have a permeability less than or equal to the permeability of the natural subsoils at the site. The cap could be constructed of earthen materials (i.e. clay) or man-made materials (i.e. asphalt). The construction of the proposed cap would include a layer of asphalt over a gravel base. An engineered cap would decrease contaminant mobility and eliminate the possibility for human exposure to contaminated soil, but would not reduce the toxicity or volume of the contaminants.

5.3.2 <u>Alternative D: Excavation/Storage/Biological Treatment/On-Site Landfill</u>

The four components of this alternative are excavation, storage, on-site biological treatment, and on-site disposal of the treated soil in a solid waste landfill. The excavated soil would be treated utilizing either windrow composting, aerobic bioslurry, or anaerobic bioslurry. Excavation, soil handling, and the construction of the optional engineered caps would be performed in a similar manner to Alternative C.

Biological treatment is proposed as the on-site treatment technology for the contaminated soil at the northern industrial areas. Windrow composting has been chosen as a biological treatment option because field-scale tests have demonstrated effective concentration reduction and toxicity reduction of explosives-contaminated soil (USAEC, 1992a; USAEC, 1993d). Aerobic bioslurry has also been chosen as an on-site treatment option for the contaminated soil because bench-scale tests have demonstrated effective treatment of soil contaminated with 2,4,6-TNT (Zappi, et al., 1993). Bench-scale and field-scale tests with anaerobic bioslurry reactors have also demonstrated effective treatment of soil contaminated with explosives compounds. After the contaminated soil has been treated, laboratory analyses of the treated soil would be performed to confirm the effectiveness of the treatment. If the levels of explosives compounds in the treated soil were below 20 μg/g (separately for 2,4,6-TNT-related compounds and RDX-related compounds) and the soil passes the TCLP and Paint Filter Liquid Test, the treated soil would be disposed in an on-site solid waste landfill. The treatment goal of 20 μg/g (separately for 2,4,6-TNT-related compounds and RDX-related compounds) has been chosen based on the limit of the treatment technology. Treated soil would be placed in a solid waste landfill because the biotransformed and non-biodegraded explosives compounds remaining in the soil would have an unknown toxicity. Therefore, the soil would be placed in a controlled environment (i.e. a solid waste landfill) where it would be isolated from human and ecological receptors and would not leach contaminants to the groundwater.

5.4 SUMMARY OF REMEDIAL ALTERNATIVES

Four alternatives have been developed, including a No Action alternative (Alternative A), a Limited Action alternative (Alternative B), and two treatment alternatives varying from on-site incineration (Alternative C) to biological treatment (Alternative D). A summary of these alternatives is presented in Table 5-1. Section 6 provides a detailed evaluation of these alternatives.

TABLE 5-1
SUMMARY OF ALTERNATIVES

ALTERNATIVE	COMPONENTS OF ALTERNATIVE
A	• No Action
B	• Limited Action
C	• Excavation • Storage • Rotary Kiln Incineration • Backfill and Cover with Topsoil • Optional Engineered Caps
D	• Excavation • Storage • Biological Treatment - Windrow Composting - Aerobic Bioslurry - Anaerobic Bioslurry • On-Site Solid Waste Landfill • Optional Engineered Caps

6.0 DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

The remedial alternatives that were developed in Section 5 are being evaluated in detail as a means of reducing risks associated with exposure to explosives-contaminated soil by workers and protecting groundwater quality. The assessment consists of evaluating each alternative using the nine criteria listed in the NCP.

The purpose of this detailed evaluation of alternatives is to provide performance and cost data which could be utilized to evaluate further remedial action at the northern industrial areas above and beyond existing and planned remedial activities (the O-Line Ponds multi-media cap; the groundwater extraction and treatment system at the O-Line Ponds area for OU1; and the O-Line Ponds Cap Extension for OU2). It should be noted that the cost estimates are reasonably conservative and are based on presently available data.

6.1 NINE EVALUATION CRITERIA

Section 300.430(e) of the NCP lists nine criteria against which each remedial alternative must be assessed. The acceptability or performance of each alternative against the criteria is evaluated individually so that relative strengths and weaknesses may be identified. The detailed criteria are as follows:

1) Protection of human health and the environment;
2) Compliance with ARARs;
3) Long-term effectiveness and permanence;
4) Reduction of toxicity, mobility, or volume through treatment;
5) Short-term effectiveness;
6) Implementability;
7) Cost;
8) State acceptance; and
9) Community acceptance.

The NCP (Section 300.430(f)) states that the first two criteria, protection of human health and the environment and compliance with ARARs, are "threshold criteria" which must be met by the selected remedial action unless a waiver is granted under Section 121(d)(4) of CERCLA. Criteria 3 through 7 are "primary balancing criteria", and the trade-offs within this group must be balanced. The preferred alternative will be the alternative which is protective of human health and the environment, ARAR-compliant, and would provide the best combination of primary balancing attributes. The final two criteria, state and community acceptance, are "modifying criteria" which are evaluated following the comment period on the RI/FS reports and the Proposed Plan.

6.1.1 Protection of Human Health and the Environment

A determination and declaration that this criterion will be met by the proposed remedial action must be made in the ROD; therefore, this is a threshold criterion which must be met by the selected remedy. This criterion would be met if the risks associated with human exposure to explosives-contaminated soil are eliminated, reduced, or controlled through treatment, engineering, or institutional controls, and if the remedial action is protective of the environment.

6.1.2 Compliance with ARARS

Compliance with ARARs is also a threshold criterion which must be met by the proposed remedial action. The alternative will meet this criterion if all chemical-specific, action-specific, and location-specific ARARs are met by the alternative. TBC guidance, such as health advisories or risk-based remediation goals are goals for this remedial action. This criterion will be used to determine if all chemical-specific, action-specific, location-specific, and TBC guidance are met. For those ARARs which are not met, a determination will be made as to whether a waiver is appropriate.

6.1.3 Long-term Effectiveness and Permanence

The level of risk associated with treatment residuals and/or untreated waste after implementation of the remedial alternative will be evaluated. Components of this analysis include the following:

- The magnitude of residual risk based on factors such as volume, toxicity, and mobility of contaminants, and their propensity to biodegrade or bioaccumulate.

- The adequacy and reliability of controls, including the need to maintain, upgrade, or replace the treatment or containment systems.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The statutory preference for remedial technologies that significantly and permanently reduce the toxicity, mobility, or volume of the waste is addressed by this criterion. The following factors are considered:

- The amount of hazardous materials that will be destroyed or treated;

- The degree of expected reduction in toxicity, mobility, or volume;

- The degree to which the treatment will be irreversible; and

- The type and quantity of treatment residuals that will remain following treatment.

6.1.5 Short-Term Effectiveness

The effects of the remedial alternative from construction and implementation to completion of the remedial alternative are addressed under this criterion. The following factors will be addressed:

- Protection of the community during the remedial action, including the effects of dust from excavation, transportation of excavated materials, and air-quality impacts from on-site treatment;

- Protection of workers during the remedial action;

- Environmental impacts of the remedial action; and

- Time required to achieve remedial response objectives.

6.1.6 Implementability

The technical and administrative feasibility of implementing the remedial action will be addressed. The technical feasibility will be evaluated on the basis of ease of construction and maintenance, reliability of the selected technology, and the ease of coordinating the technology with remedial actions for other OUs at MAAP.

6.1.7 Cost

The capital costs, operating and maintenance costs, and present worth of each remedial action will be considered. In addition, the accuracy of the cost estimates will be considered. Cost sensitivity analyses may be performed if it is determined that a large amount of uncertainty exists in assumptions made for costing.

6.1.8 State Acceptance

State acceptance, a "modifying criterion", will be evaluated following the comment period for this Focused FS report and the Proposed Plan.

6.1.9 Community Acceptance

Community acceptance, a "modifying criterion", will be evaluated following the comment period for this Focused FS report and the Proposed Plan.

6.2 DETAILED ANALYSES OF ALTERNATIVES

6.2.1 Alternative A: No Action

6.2.1.1 Description. Under this alternative, no further action would be taken to address contamination at the northern industrial areas. The No Action alternative is intended to serve as a baseline with which to compare the risk reduction effectiveness of other potential alternatives. For the No Action alternative, it is assumed that future use of the northern industrial areas would be industrial. It is also assumed that the areas outside of the industrial areas could be developed for residential use. In this case, residents could be exposed to contaminants that leach from soil into the groundwater. Five-year reviews would be required by the NCP because contamination would remain at the northern industrial areas.

6.2.1.2 Overall Protection of Human Health and the Environment. The potential risks to human health and the environment presented in the remedial action objectives are based on the No Action alternative. The No Action alternative does not decrease the potential risks to humans or the environment in any way, as no remedial activities would be implemented at the northern industrial areas under this alternative. Therefore, the No Action alternative would not be protective of human health and the environment because the risks associated with ingestion of contaminants that leach to groundwater from the soil and migrate to nearby hypothetical residential areas and direct contact with explosives-contaminated soil by workers would continue to be above the acceptable risk range.

6.2.1.3 Compliance with ARARs. There are no promulgated standards for levels of explosives compounds in soil. Therefore, chemical specific ARARs do not apply to this action. Because no remedial activities would be implemented under the No Action alternative, location-specific and action-specific ARARs also do not apply.

6.2.1.4 Long-Term Effectiveness and Permanence. Over the long term, this alternative would not be effective in controlling worker exposure to explosives-contaminated soil or the leaching of explosives compounds to groundwater. However, over time, the levels of explosives compounds in the surface soil may be reduced by intrinsic biodegradation of the explosives compounds within the soil or by leaching of the explosives compounds to the groundwater.

6.2.1.5 Reduction of Toxicity, Mobility, or Volume Through Treatment. Implementation of the No Action alternative would not result in a reduction of toxicity, mobility, or volume through treatment. However, over time, a reduction in the mass of explosives compounds within the soil may occur through intrinsic biodegradation.

6.2.1.6 Short-Term Effectiveness. There would be no short-term risks associated with the No Action alternative because no additional remedial activities would be implemented at the northern industrial areas for the explosives-contaminated soil.

6.2.1.7 Implementability. There would be no implementability concerns associated with the No Action alternative because no further remedial activities would be conducted at the northern industrial areas for the explosives-contaminated soil.

6.2.1.8 Cost. There would be no cost associated with the No Action alternative because no remedial activities would be conducted at the northern industrial areas.

6.2.2 Alternative B: Limited Action

6.2.2.1 Description. The Limited Action alternative would include implementation of the following actions:

- Institutional restrictions to limit future land uses to industrial usage;
- Maintenance of existing fences to prevent trespassers from being exposed to the explosives-contaminated soil;
- Public education programs; and
- Five-year reviews.

Institutional controls include continued access restrictions, deed restrictions, and land use restrictions. Access restrictions include administrative actions to levy fines against trespassers and long-term maintenance of the fences currently in place around the northern industrial areas. Deed and land use restrictions would limit the future uses at the individual sites and require permits, qualified supervision, and health and safety precautions for any activities conducted in the vicinity of the northern industrial areas. Education programs would be developed to inform workers and local residents of the potential site hazards.

Five-year reviews are required by the NCP at all sites where hazardous chemicals remain untreated. The review would analyze available data to make a determination as to whether additional remedial actions would be required at the northern industrial areas.

6.2.2.2 Overall Protection of Human Health and the Environment. Compared to the No Action alternative, this alternative would provide a minimal reduction in human health risks by limiting future use and development of the affected areas of the northern industrial areas. Intrinsic biodegradation of the explosives compounds by indigenous microorganisms within the soil and leaching of the explosives compounds to the groundwater would still occur under this alternative. This alternative would not include further action to reduce, eliminate, or contain the source, or to reduce contaminant migration. Therefore, the Limited Action alternative would not satisfy this criterion.

6.2.2.3 Compliance with ARARs. There are no promulgated standards for levels of explosives compounds in soil. Therefore, chemical specific ARARs do not apply to this action. Because no remedial activities would be implemented under the No Action alternative, location-specific and action-specific ARARs also do not apply.

6.2.2.4 Long-Term Effectiveness and Permanence. Since treatment or containment of the explosives-contaminated soil would not be performed, risks would not be reduced below the current risks posed by the explosives-contaminated soil at the northern industrial areas. Therefore, workers would continue to be exposed to levels of explosives compounds above risk-based levels and the explosives compounds would continue to leach to the groundwater from the soil. However, the chemical concentrations in the soil may be reduced over many years by intrinsic biodegradation of the explosives compounds within the soil or by leaching of the explosives compounds into the groundwater.

6.2.2.5 Reduction of Toxicity, Mobility, or Volume Through Treatment. Implementation of the Limited Action alternative would not result in the reduction in the toxicity, mobility, or volume of the explosives-contaminated soil at the northern industrial areas because removal or treatment of the explosives-contaminated soil would not be components of this alternative. However, over time, a reduction in the mass of explosives compounds within the soil may occur through intrinsic biodegradation.

6.2.2.6 Short-Term Effectiveness. There would be no short-term risks associated with the Limited Action alternative because no additional remedial activities would be implemented at the northern industrial areas for the explosives-contaminated soil.

6.2.2.7 Implementability. All components of Alternative B are feasible and could be easily implemented. All necessary equipment and materials required for implementation of this alternative are readily available. Administrative implementation of this alternative would require coordination between MAAP, TDEC, and USEPA Region IV to ensure continuity of the long-term management and monitoring of the sites.

Five-year reviews would be required as part of the long-term monitoring program because residual contaminants would remain on site. Implementation of Alternative B would be consistent with any additional future actions at the site. In fact, all components of Alternative B are also components of each of the alternatives evaluated for the northern industrial areas, with the exception of Alternative A (No Action).

6.2.2.8 Cost. The capital costs are estimated to be $27,000 for this alternative, as itemized in Table 6-1. Annual O&M costs are $39,000. Total present worth costs for this alternative based on a 30-year (5% discount rate) implementation period are $626,000. Maintenance of the existing fences is included in the annual operating cost for this alternative. Contingencies associated with the Limited Action alternative would be minimal because this alternative does not include any complex treatment or design components.

6.2.3 Alternative C: Excavation/Storage/Incineration/Backfill

6.2.3.1 Description. This alternative would consist of excavating soil from the northern industrial areas that is contaminated with explosives compounds above the risk-based remedial action objective of 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds to a maximum depth of 10 feet, followed by on-site thermal treatment. The treated soil would be used as backfill for the areas where explosives-contaminated soil was excavated. Clean soil from a borrow area at MAAP would be used to resurface the backfilled areas, and the areas would be revegetated. The detailed analysis is based on rotary kiln incineration technology, which has been effectively demonstrated for the remediation of explosives-contaminated soil in previous pilot-scale studies (USAEC, 1984). Using incineration,

Table 6-1
Summary of Costs for Alternative B: Limited Action

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. ADMINISTRATIVE ACTIONS					
1. Institutional Restrictions (a)		$0	$1,000	$15,000	$9,000
2. Public Education Program (b)		$20,000	$2,000	$31,000	$19,000
3. Program Oversight (c)			$25,000	$384,000	$236,000
Subtotal:		$20,000	$28,000	$430,000	$264,000
II. LONG-TERM MONITORING & REVIEW					
1. Five-Year Reviews ($15,000 ea) (d)	6 reports		$3,000	$46,000	$28,000
Subtotal:		$0	$3,000	$46,000	$28,000
SUBTOTAL (I and II)		$20,000	$31,000	$476,000	$292,000
III. ADDITIONAL SYSTEM COSTS					
1. Health and Safety — 0% of Capital subtotal		$0			
2. Bid Contingency — 15% of Capital subtotal		$3,000			
3. Scope Contingency — 15% of Capital subtotal		$3,000			
25% of Annual subtotal			$8,000	$123,000	$75,000
Subtotal:		$6,000	$8,000	$123,000	$75,000
CONSTRUCTION SUBTOTAL (I, II, and III)		$26,000	$39,000	$599,000	$367,000
VI. IMPLEMENTATION COST					
1. Eng. Services During Construction — 0% of System subtotal		$0			
2. Engineering & Design — 0% of System subtotal		$0			
3. Permitting/Coordination/Legal — 5% of Capital costs		$1,000			
Subtotal:		$1,000	$0	$0	$0
A. TOTAL CAPITAL COSTS		$27,000			
B. TOTAL ANNUAL COSTS			$39,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$599,000	$367,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$626,000	$394,000

Notes:

(a) – Includes annual maintenance of the fences around the northern industrial areas. Institutional restrictions would limit land use to industrial.
(b) – Includes increased public awareness of site hazards and actions through press releases, presentations, and posting of signs.
(c) – Costs include the annual salary of one part time program oversight manager. Costs do not include government oversight of this task.
(d) – Reviews and reports of site conditions are required every 5 years by CERCLA because wastes will remain on site.

excavated soil would be treated to levels that would be acceptable for placement of the treated soil on the ground. Start-up of this alternative would include characterization of the soil to be treated and a test burn to optimize treatment performance of the incinerator. Figure 6-1 illustrates a process flow diagram for this alternative. Additionally, optional engineered caps would be used to cover explosives-contaminated soil in areas where excavation would be uneconomical or impractical (i.e. where the stability of a building foundation would be compromised by excavation).

This alternative would also include institutional restrictions, maintenance of the existing fences and public education programs as described in Alternative B.

6.2.3.2 Excavation. The estimated volume of the explosives-contaminated soil to be excavated incorporates a twenty percent bulking factor for the increase in soil volume upon excavation. Additionally, soil density is assumed to be 1.7 tons per cubic yard (125 pounds/cubic foot). Based on the results of sampling at Line B (as discussed in Section 3.0), the total volume of explosives-contaminated soil to be excavated has been estimated to be approximately 22,200 yd^3. Conventional earthmoving equipment such as backhoes, draglines, or other earthmoving equipment would be used for excavation of the explosives-contaminated soil. The rate of excavation would be adjusted to ensure that a 1.5 week buffer volume would be stored in the stockpile area. This stockpile would allow incineration to proceed during inclement weather when excavation would be difficult.

The actual volume of soil to be excavated would be based on analysis of soil samples collected during excavation. Field test kits capable of analyzing soil for 2,4,6-TNT-related compounds and RDX-related compounds would be used to determine the concentration of explosives compounds in the soil removed from the excavated section relative to the risk-based remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds. Also, confirmatory sampling would ensure that the remaining soil does not exceed the risk-based remedial action objectives developed in Section 3.

The excavation areas would require site preparation by clearing and grubbing existing surface vegetation and stripping grass from the site. During clearing, grubbing, and excavation activities, dust suppression and erosion control measures would be implemented. Air monitoring stations would be positioned to ensure compliance with Tennessee Air Pollution regulations that govern particulate emissions.

6.2.3.3 Soil Storage. Soil would be stored in a semi-enclosed steel building to prevent windblown contamination, precipitation run-on to the soil pile, and run-off from the soil pile. Adequate space would be provided for an appropriate stockpile of soil. The height of the soil storage building would be designed to account for the tipping height of the dump trucks. A decontamination area would be provided to clean the tires of dump trucks and front-end loaders which travel into and out of the soil storage area.

6.2.3.4 Rotary Kiln Incineration. The basic components of a rotary kiln incineration system would be the soil feed system, primary kiln, the secondary combustion chamber, air quality control system, and ash removal system. A process flow diagram for a typical rotary kiln incineration system is presented in Figure 6-2. Wastes and auxiliary fuel would enter the incinerator and be combusted with excess oxygen. Mixing of wastes would occur through rotation of the combustion chamber. This mixing would assist in the combustion of waste materials. Waste materials would be transformed into ash and combustion gases, including carbon dioxide and water. A secondary combustion chamber would be used to ensure complete combustion of gases. Off-gases would be treated to remove acid gases and particulates, and ash (decontaminated soil) would be removed at the lower end of the unit. This technology has been used for remediation of explosives-contaminated soil at SADA, Savanna, Illinois, at Cornhusker Army Ammunition Plant, Grand Island, Nebraska, and at LAAP, and will be implemented at

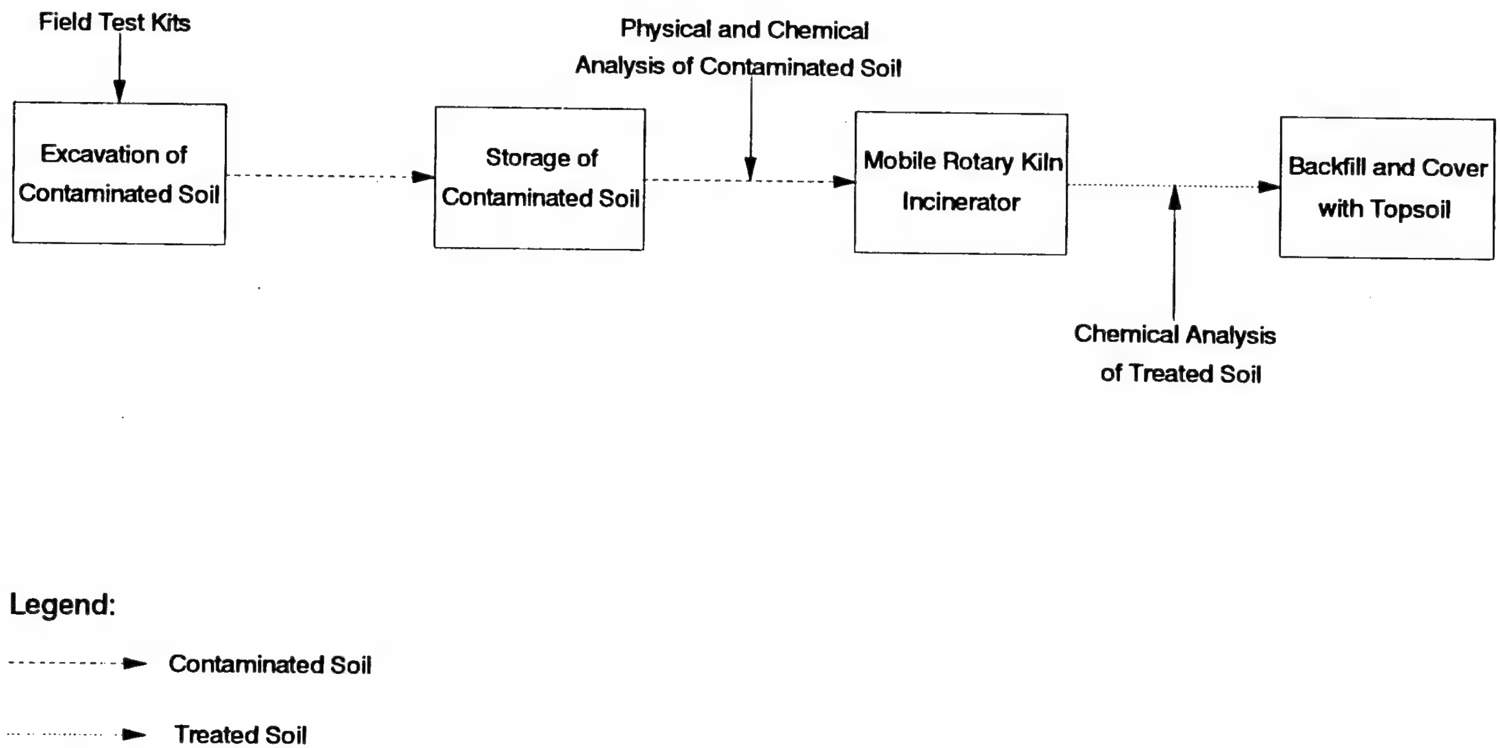
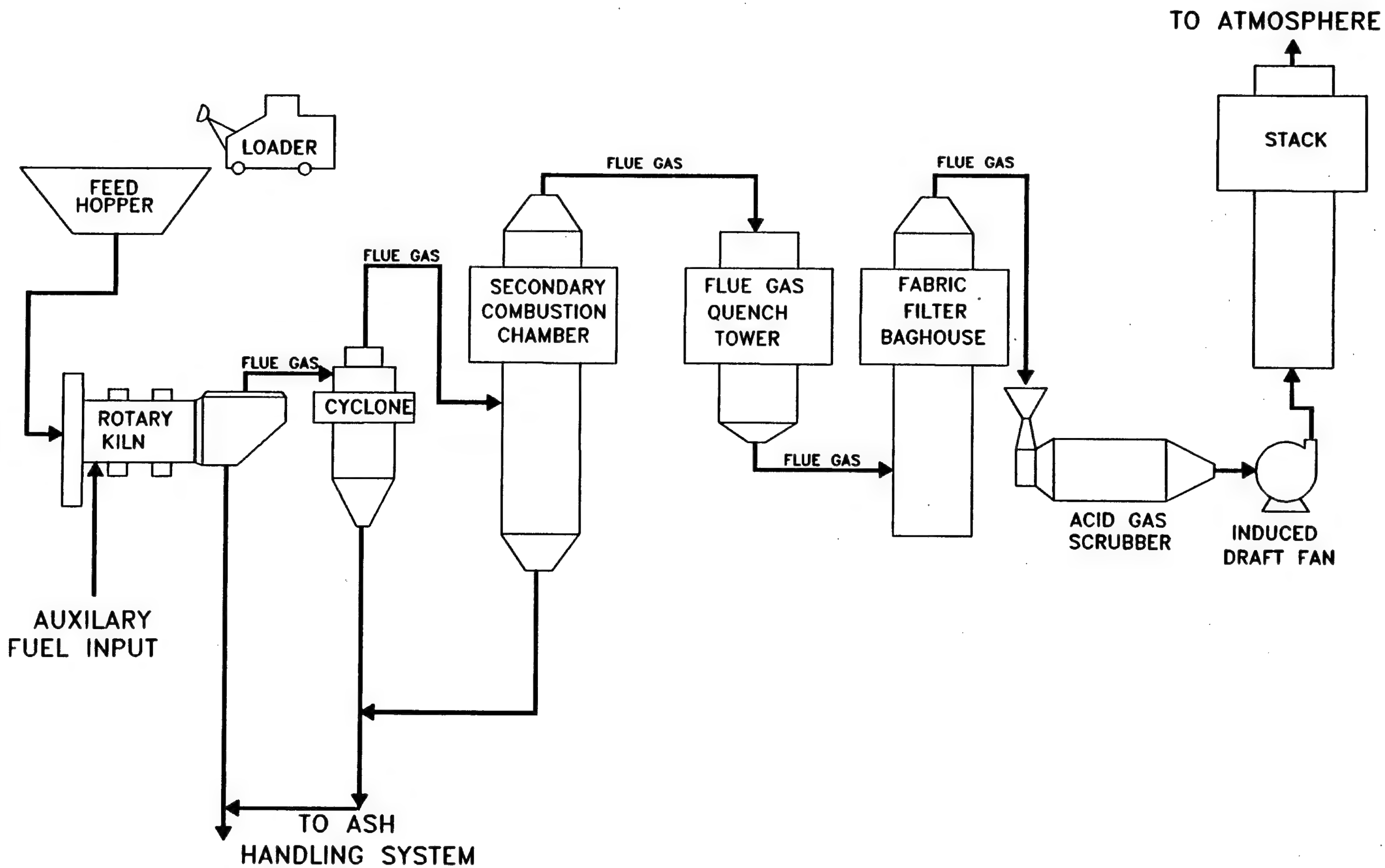


Figure 6-1
Process Flow Diagram for Excavation/Storage/Incineration/Backfill



SOURCE: Adapted from ThermAll, Inc.

FIGURE 6-2 PROCESS FLOW DIAGRAM FOR ROTARY KILN INCINERATION

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Alabama Army Ammunition Plant. In a pilot-scale treatability study, DREs of greater than 99.99 percent were achieved using a rotary kiln incinerator (USAEC, 1984). The results of these studies are presented in Appendix C.

Soil Incineration at the Northern Industrial Areas. Based on the volume of soil requiring treatment, a mobile rotary kiln incineration system with a design soil feed rate of 5 tons per hour is proposed. Mobilization, set-up, and demobilization of the mobile system onto the site would be required and would be simpler than for a fixed unit built at the site. The rotary kiln would be automated with system controls and instrumentation that could continuously monitor and maintain the processing parameters. In the event of a process upset, the computer logic systems would be automatically programmed to shut off the incineration process.

Prior to incineration, excavated soil would be hauled to a central storage building where it would be stockpiled. From the staging area, the soil would be sent to the incinerator feed hopper via a conveyor belt or other bulk loading system. The conveyor would then transfer the soil to a screw feeder which would feed it into the primary kiln. In order to control the feed rate, a weigh-belt conveyor could be used to transport the soil. This type of conveyor would utilize an electronic scale to provide closed-loop feedback to the main programmable logic system controller and maintain a constant feed rate.

The primary kiln would consist of a rotating, refractory-lined cylinder which would be slightly inclined from the horizontal. Three inputs would enter the combustion chamber at the high end of the rotary kiln: waste (i.e. explosives-contaminated soil), auxiliary fuel (e.g. natural gas), and air or oxygen. The rotating of the combustion chamber would allow for improved mixing and combustion of contaminants. Upon combustion, the waste material would be reduced to flue gas and inert ash, which would move toward the low end of the cylinder. A stationary refractory-lined end panel would connect the primary kiln to both the secondary combustion chamber and the ash discharge. Discharged ash from the primary kiln should be free of organic content. Flue gas generated in the primary kiln would pass through the end panel and be fed to the secondary combustion chamber. A scalping cyclone could be installed after the primary kiln and prior to the secondary combustion chamber. The cyclone would further enhance the separation of fly ash from the flue gas generated in the incineration process.

The secondary combustion chamber would be a stationary, refractory-lined combustion chamber which would operate at higher temperatures than the primary kiln, typically in the range of 2,200°F to 2,500°F. In the secondary combustion chamber, flue gas from the primary kiln would be combusted by mixing with excess air and auxiliary fuel. Inert ash from both the primary kiln and secondary combustion chamber would be discharged onto conveyors and collected by the ash collection system.

Flue gas exiting the secondary combustion chamber would be sent through a heat exchanger to reduce the flue gas temperature prior to contacting the baghouse filter collection unit. A wet scrubber could also be incorporated as a component of the air quality control system following the fabric filter unit. The wet scrubber would utilize lime or caustic soda solutions to remove fine particulates and acid gases from the flue gas. Residuals from the scrubber process could be neutralized, filtered, and recycled back to the scrubber in order to minimize wastewater discharges. The treated flue gas would flow through an induced draft fan and would be exhausted via a stack. To confirm compliance with the established emissions standards, in-line continuous samplers would be utilized to monitor the flue gas emissions.

Waste Characterization. A composite sample of the explosives-contaminated soil from the stockpile area would be analyzed daily. This daily composite sample would be analyzed for various physical and chemical properties such as explosives concentrations, ash content, elemental analysis, and moisture content. The results of this analysis would be used to adjust the operating parameters of the mobile incinerator. A detailed discussion of the effects of these parameters on incinerator performance is presented in Appendix C. A daily composite sample of the treated soil would verify the effectiveness

of incineration. The treated soil would be analyzed for explosives concentrations, and the TCLP test. If the TCLP test indicates that the incinerated waste is non-hazardous, the treated soil would be backfilled into the area where the explosives-contaminated soil was excavated. In the event the treated soil is determined to be hazardous, the corresponding treated soil pile would be fed back into the incinerator for further treatment.

Test Burn. Before the test burn, the soil would be analyzed to determine certain waste characteristics such as heating value, moisture content, ash content, elemental analysis, explosives content, metals content, and soil density. A test burn would be performed to determine if the incineration facility is capable of destroying the explosives compounds to a DRE of 99.99 percent. During the test burn, several factors would be monitored including the concentrations of carbon monoxide, oxygen, particulates, oxides of nitrogen and sulfur, and halogenated compounds in the stack gas. If all factors meet Federal and State compliance standards while using a representative waste stream, full-scale treatment would begin.

6.2.3.5 Backfilling of Treated Soil. Explosives compounds in soil treated by incineration would not be present above analytical detection limits; therefore, the decontaminated soil would be suitable as backfill material. The treated soil would be placed into the areas where the explosives-contaminated soil was excavated, compacted, and covered with a layer of topsoil.

The topsoil would be obtained from a clean area at MAAP. The appropriate soil would contain no explosives compounds or other organic contaminants, and levels of metals would be within the background range. After excavating and transporting the topsoil, it would be placed over the treated soil with standard earthmoving equipment. Compaction and grading of placed soil would be performed by conventional equipment such as a front-end loader or bulldozer. The topsoil would not be compacted to encourage vegetation growth.

After placement of the topsoil, the new surface would be seeded with grasses and other durable vegetation. Other measures to control erosion, such as placement of geotextile erosion control materials on the perimeter of the soil cover, would be taken to ensure the integrity of the covering.

6.2.3.6 Optional Engineered Caps. There are certain areas within the northern industrial areas where excavation of the soil containing explosives compounds above the remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds may be uneconomical or impractical. Large excavations in the vicinity of active load lines may be dangerous to workers within these areas. In some cases, excavation activities performed adjacent to large buildings could undermine building foundations. Under this option, select areas of explosives-contaminated soil would be left in place and engineered caps would be placed over areas where the soil contains explosives compounds above the remediation goals. The use of engineered caps would reduce direct exposure to the contaminants within the soil and protect groundwater quality.

The engineered caps would be designed to prevent human exposure to the soil and minimize the leaching of contaminants to groundwater. The construction of the caps would include a 3-inch layer of asphalt over a 6-inch gravel base. The caps would be installed to extend beyond areas of explosives-contaminated soil, to ensure complete coverage. The engineered caps would eliminate the possibility for human exposure to the explosives-contaminated soil and would prevent the infiltration of rainwater through the soil; this would greatly reduce the leaching of explosives compounds to groundwater.

Implementation of this option would require site preparation by clearing and grubbing existing surface vegetation, stripping grass from the site, and preparing the surface for placement of the engineered caps. During clearing and grubbing activities, dust suppression and erosion control measures would be implemented to control migration of contaminants via wind and stormwater erosion.

A gravel layer would be placed over the soil with standard earthmoving equipment to serve as a foundation layer. Compaction of placed gravel may be part of the placement process. However, surface settlements of placed gravel would probably be minimal because of the small thickness involved.

After placement of the gravel, the asphalt layer would be applied. Asphalt would be obtained locally and applied using conventional paving equipment. The asphalt layer would have a lower permeability than the soil to be covered.

6.2.3.7 Overall Protection of Human Health and the Environment. The excavation, incineration, and backfilling portion of this alternative would ensure the protection of human health and the environment by removing and destroying or covering the soil containing explosives compounds above risk-based levels in the northern industrial areas. Soil with explosives compounds greater than 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds would be removed from the areas and treated, reducing the risk associated with potential migration and exposure pathways. The levels of explosives compounds in the excavated soil would be reduced by at least the DRE of 99.99 percent.

The optional engineered caps would also reduce the risk levels posed by the explosives-contaminated soil at the northern industrial areas. Covering areas of explosives-contaminated surface soil in areas where excavation is uneconomical or impractical would prevent potential dermal absorption and incidental ingestion exposures, and leaching of explosives compounds to groundwater. After construction is complete, workers at the facility and potential future residents would not be exposed to the explosives-contaminated soil because the engineered caps would provide a physical barrier to the contaminants, and the caps would provide an impermeable barrier to prevent the leaching of the explosives compounds to groundwater.

During the remediation activities, short-term protection of public health would be adequately provided through access restrictions and the minimization of airborne emissions. Personnel working at the excavation site would be equipped with proper personal protection equipment to minimize potential exposure.

6.2.3.8 Compliance with ARARs. There are no promulgated standards for levels of explosives compounds in soil. Therefore, chemical specific ARARs do not apply to this action.

All components of this alternative would be in compliance with action-specific ARARs. Incineration, if properly implemented and performed within the established operating parameters, would achieve DREs of 99.99 percent. The use of an air pollution control system would ensure compliance with incinerator emissions standards. In the event of a process upset, the computer logic systems would be automatically programmed to shut off the incineration process. Backfilling and covering of the treated soil would be conducted within proper regulations. Action-specific ARARs which apply to landfill and surface impoundment closures would be met by the optional engineered caps because the cover material would have a lower permeability than the underlying soil (40 CFR 264.228.). Groundwater monitoring for the optional engineered caps would be performed under a separate operable unit to evaluate groundwater protection.

There are no location-specific ARARs that apply to this alternative. Excavation, incineration, and backfilling or the optional engineered caps would be performed in compliance with the State of Tennessee regulations concerning fugitive dust. Non-point source emissions of explosives-contaminated particulates by wind and stormwater erosion that could be generated during clearing, grubbing, and earthwork would be controlled by water spray and erosion controls. These controls would ensure compliance with Tennessee Air Pollution Control regulations concerning particulate emissions (Rule 1200-3-7.03(2)) and the substantive requirements of the Tennessee Water Pollution Control Regulations general stormwater permit program for construction activities (Rule 1200-4-10.05).

6.2.3.9 Long-Term Effectiveness and Permanence. The excavation, incineration, and backfilling remedial actions proposed in this alternative would provide long-term effective and permanent protection. Permanent destruction and irreversible reduction of the explosives compounds within the excavated soil would be achieved by incineration. Incineration has been demonstrated to provide 99.99 percent DREs for explosives-contaminated soil at other Army ammunition plants (see Appendix C). Final concentrations of explosives compounds in the treated soil would be below method detection limits, which corresponds to an excess cancer risk of less than $1x10^{-5}$ for all exposure pathways at the site. Complete incineration, followed by backfilling and covering of the treated soil, would be a permanent solution to protect workers and groundwater quality at the northern industrial areas.

If properly maintained, the optional engineered caps would provide long-term isolation of explosives-contaminated surface soil, and would prevent contaminant leaching to groundwater. Human exposures to surface soil via direct contact and incidental ingestion would be eliminated and groundwater would be protected. Additionally, the concentration of explosives compounds in the soil under the optional engineered caps may be reduced over many years by intrinsic biodegradation.

Access controls that are already in place, such as the existing fences, would require maintenance. The optional engineered caps would require periodic maintenance to ensure their impermeability. Erosion control and mowing of the treated soil disposal areas would both be required.

6.2.3.10 Reduction of Toxicity, Mobility or Volume Through Treatment. Under this alternative, incineration would be used to reduce the toxicity, mobility, and volume of contaminants through treatment.

The optional engineered caps would not include a treatment process, but rely on containment only. No contaminants would be treated or destroyed; therefore, toxicity and volume of the explosives-contaminated soil would not be reduced. However, the engineered caps would provide some reduction of contaminant mobility. All surface transport pathways (i.e. wind erosion and surface water runoff) would be eliminated, and vertical migration to groundwater would be reduced.

6.2.3.11 Short-Term Effectiveness. Short-term risks to workers, the public, and the environment during construction and implementation of this alternative are expected to be minimal. Access restrictions would be effective in minimizing risks in the short term. Air quality would be monitored to correct any windblown emissions of explosives-contaminated dust during excavation. In addition, silt fences may be utilized for erosion control during the excavation, treated soil backfilling, and optional engineered cap construction processes. Personnel working at the excavation site would be equipped with proper personal protection equipment to minimize potential exposure. Air pollution control devices that treat exhaust gases from the incinerator would minimize emissions of toxic gases and particulates from the treatment system.

Implementation of this alternative, from design to implementation of the clean soil cover over the treated soil, would require approximately 27 to 32 months. The thermal treatment technology is commonly used and commercially available. The design, review, and procurement of the equipment and materials for the excavation and thermal treatment system would require approximately 12 months. The mobilization and set-up of the mobile incineration would require 1 to 2 months. Start-up test burns would require 2 to 3 months for completion. Once the incinerator is at full-scale operation, complete remediation of the soil containing explosives compounds above risk-based remedial action objectives from the northern industrial areas could be completed in approximately 12 to 15 months.

6.2.3.12 Implementability. Rotary kiln incineration has been demonstrated to effectively treat explosives-contaminated soil at other sites. Rotary kiln incineration systems are commonly used for the destruction of organic contaminants, and are commercially available. A site-specific test burn would be conducted to establish the range of operating parameters that meet the regulatory requirements.

Operation of the incinerator would require twenty-four hour supervision. Personnel required per shift for the incinerator would include a loader, control operator, stand-by maintenance person, and supervisor. Additional personnel would be required for soil testing and other site work.

Utility requirements for the rotary kiln incineration system include electricity, water, and auxiliary fuel. Monitoring of influent soil characteristics, operating parameters, residual characteristics, water discharges, and air and particulate emissions would be required. The incineration system is expected to operate 80 percent of the time with 20 percent downtime for periodic maintenance. With proper maintenance, the normal lifetime of the incinerator would exceed the project period.

Covering the explosives-contaminated surface soil with the optional engineered caps in areas where excavation would be uneconomical or impractical would be relatively easy to implement. Appropriate materials (gravel) could be obtained from local sources. Other materials, such as asphalt and erosion control netting, are commercially available. All required equipment for earthwork and asphalt paving is also commonly available.

Additional actions, such as repair to the asphalt, would be relatively simple to implement. Periodic monitoring and maintenance would include visual inspection of the individual engineered caps to ensure they are still intact, and to evaluate whether erosion controls are functioning properly.

Five-year reviews would be required as part of the long-term monitoring program because residual contaminants would remain on site. The tasks associated with coordinating the management of this alternative would be feasible and implementable.

6.2.3.13 Cost. A detailed cost estimate is presented in Appendix B for the excavation, incineration, and backfilling and the optional capping of the soil with concentrations of explosives compounds above the remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds. Table 6-2 summarizes estimated cost for the excavation and incineration alternative.

Capital costs included in the alternative are site preparation, mobilization, set-up, and test burn costs. The total present worth of this alternative is estimated to be $24,700,000 (5% discount rate), including capital costs of $24,100,000 and annual O&M expenditures of $40,000. These costs are preliminary and are subject to change. Initial costs are based on vendor information and generic unit costs.

6.2.4 Alternative D: Excavation/Storage/Biological Treatment/On-Site Landfill

6.2.4.1 Description. Soil from the northern industrial areas with explosives levels above the risk-based remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds would be excavated under this alternative to a maximum depth of 10 feet. Clean soil from a borrow area at MAAP would be used as backfill for the excavated areas. The excavated soil would be treated using either windrow composting, aerobic bioslurry, or anaerobic bioslurry. The treated soil would then be disposed as a solid waste in an on-site solid waste landfill in order to contain the biotransformed and non-biodegraded explosives compounds of unknown toxicity which would remain in the treated soil. The soil would be placed in a controlled environment where it would be isolated from human and ecological receptors and would not leach contaminants to the groundwater. Figures 6-3 and 6-4 present flow diagrams for the windrow composting and bioslurry treatment systems under this alternative. Bench- and field-scale studies have demonstrated concentration reductions and leachable toxicity reductions of explosives-contaminated soil using biological treatment. Start-up of the biological treatment system would include studies to evaluate treatment performance given the explosives-contaminated soil characteristics, indigenous microorganisms, and available amendments. Additionally, optional engineered caps would

Table 6-2
Cost Estimate for Alternative C: Excavation/Storage/Incineration/Backfill

ITEM		QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. ADMINISTRATIVE ACTIONS						
1. Institutional Restrictions (a)			$0	$1,000	$15,000	$9,000
2. Public Education Program (b)			$20,000	$2,000	$31,000	$19,000
3. Program Oversight (c)				$25,000	$384,000	$236,000
Subtotal:			$20,000	$28,000	$430,000	$264,000
II. GENERAL ACTION/ SITE PREPARATION						
1. Incinerator Pad (d)			$135,000			
2. Contaminated Soil Storage (e)			$140,000			
3. Roadways (f)			$14,000			
4. Site Clearing & Grubbing (g)			$16,000			
5. Treated Soil Storage (h)			$13,000			
6. Lighting (i)			$190,000			
7. Contaminated Soil Excavation and Hauling (j)			$643,000			
8. Treated Soil Backfilling and Compaction (k)			$181,000			
9. Soil Cover (l)			$16,000			
10. Optional Engineered Caps (m)			$19,000			
Subtotal:			$1,370,000	$0		
III. INCINERATOR CONSTRUCTION AND OPERATION						
1. Soil Handling Equipment (n)			$303,000			
2. Contractor Mobilization (o)			$500,000			
3. Demobilization (p)			$500,000			
4. Trial Burn (q)			$750,000			
5. Operation of Kiln ($300/ton) (r)		38,000 tons	$11,400,000			
6. Soil Sampling Before and After Incineration (s)			$1,370,000			
Subtotal:			$14,800,000			
IV. LONG-TERM MONITORING, REVIEW, & MAINTENANCE						
1. Optional Engineered Cap Maintenance				$1,000	$15,000	$9,000
2. Five-Year Reviews ($15,000 ea)		6 reports		$3,000	$46,000	$28,000
Subtotal:			$0	$4,000	$61,000	$37,000
SUBTOTAL (I, II, III and IV)			$16,200,000	$32,000	$491,000	$301,000
V. ADDITIONAL SYSTEM COSTS (t)						
1. Health and Safety	10% of Capital subtotal		$1,620,000			
2. Bid Contingency	15% of Capital subtotal		$2,430,000			
3. Scope Contingency	15% of Capital subtotal		$2,430,000			
	25% of Annual subtotal			$8,000	$123,000	$75,000
Subtotal:			$6,480,000	$8,000	$123,000	$75,000
CONSTRUCTION SUBTOTAL (I, II, III, IV and V)			$22,700,000	$40,000	$614,000	$376,000
VI. IMPLEMENTATION COST						
1. Eng. Services During Construction (u)	5% of System subtotal		$670,000			
2. Engineering & Design (v)	5% of System subtotal		$670,000			
3. Permitting/Coordination/Legal (w)			$25,000			
Subtotal:			$1,370,000			
A. TOTAL CAPITAL COSTS			$24,100,000			
B. TOTAL ANNUAL COSTS				$40,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS					$614,000	$376,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)					$24,700,000	$24,500,000

Table 6-2 (continued)
Cost Estimate for Alternative C: Excavation/Storage/Incineration/Backfill

NOTES AND ASSUMPTIONS

(a) – Includes annual maintenance of the fences around the northern industrial areas. Institutional restrictions would limit land use to industrial.
(b) – Includes increased public awareness of hazards through press releases, presentations, and posting of signs.
(c) – Costs include the annual salary of one part time program oversight manager. Costs do not include government oversight of this task.
(d) – Incineration system requires a firm and level foundation. A 6" concrete pad encompassing 1/2 acre will be prepared for the equipment.
(e) – A 100 ft x 100 ft x 28 ft, 3–sided steel building will provide storage for the excavated soil to be treated. Components of the building include a concrete floor, decon pad, lighting, and a leachate collection sump. The height of the building allows for the tipping height of the dump trucks. No columns allow for easy access for trucks and loaders.
(f) – A 24–foot wide roadway will allow access to the incineration site.
(g) – Clearing of surrounding vegetation, leveling and compacting to prepare for the incineration equipment, storage and staging areas.
(h) – Size of treated soil stockpile area is based on a 1.5–week storage capacity. Treated soil holding area requires asphalt paving with curb.
(i) – Sight lighting consists of 87 20–ft aluminum light poles, light fixtures, and 400–watt mercury vapor lamps installed using conventional earthworking equipment and procedures. 1000 square feet illumination area per light is assumed.
(j) – Excavation includes removing the top 2" of topsoil and vegetation, excavating to a maximum depth of 10 feet, performing on–site screening to determine the extent of contamination, and lab confirmation of screening results.
(k) – Treated soil will be disposed in the area where the explosives–contaminated soil was excavated.
(l) – An 8–inch thick clean soil cover will be placed over the treated soil, and the areas will be reseeded.
(m) – A 3–inch layer of asphalt over a 6–inch layer of gravel will be placed on soil with explosives levels above the risk–based remediation goals in areas where excavation is impractical or uneconomical.
(n) – Two front–end loaders will be rented for the duration of treatment to handle the contaminated soil and for loading/unloading the incinerator.
(o) – These costs are typically charged by the vendor for transportation of the incineration system to the site, set–up and assembly, including an initial system start to verify that the unit is operating properly.
(p) – These costs are typically charged by the vendor for disassembly and decontamination of the mobile incinerator and transportation of the incineration system from the site.
(q) – A test burn is performed during the start–up of the incinerator to verify the 99.99% DRE of the explosives compounds.
(r) – The incineration process consists of a mechanical feed system, the primary kiln, secondary combustion chamber, air pollution control system, and ash collection system. $300/ton treatment costs are assumed.
(s) – One daily composite influent sample will be tested for explosives, TAL/TCL, ash content, total weight, and ultimate analysis (C,H,Cl,N,S). The effluent sample will be analyzed for explosives, metals, TCLP, corrosivity, ignitability, and reactivity.
(t) – Scope and bid contingencies are generally high for soil incineration due to the number of unknowns, particularly the properties of the soil to be treated which may affect the soil feed rate into the incinerator. The O&M contingency is higher than the capital cost contingency because the O&M cost estimates for the optional engineered caps may change considerably based on the number of caps placed.
(u) – Engineering services during construction would be low because the majority of the costs have already been included in the operating cost of the mobile rotary kiln incinerator.
(v) – Engineering and design costs are low because the mobile rotary kiln incinerator has already been designed by the incinerator contractor.
(w) – Cost includes permit application process and/or coordination with State/Federal officials regarding disposal of treated soil.

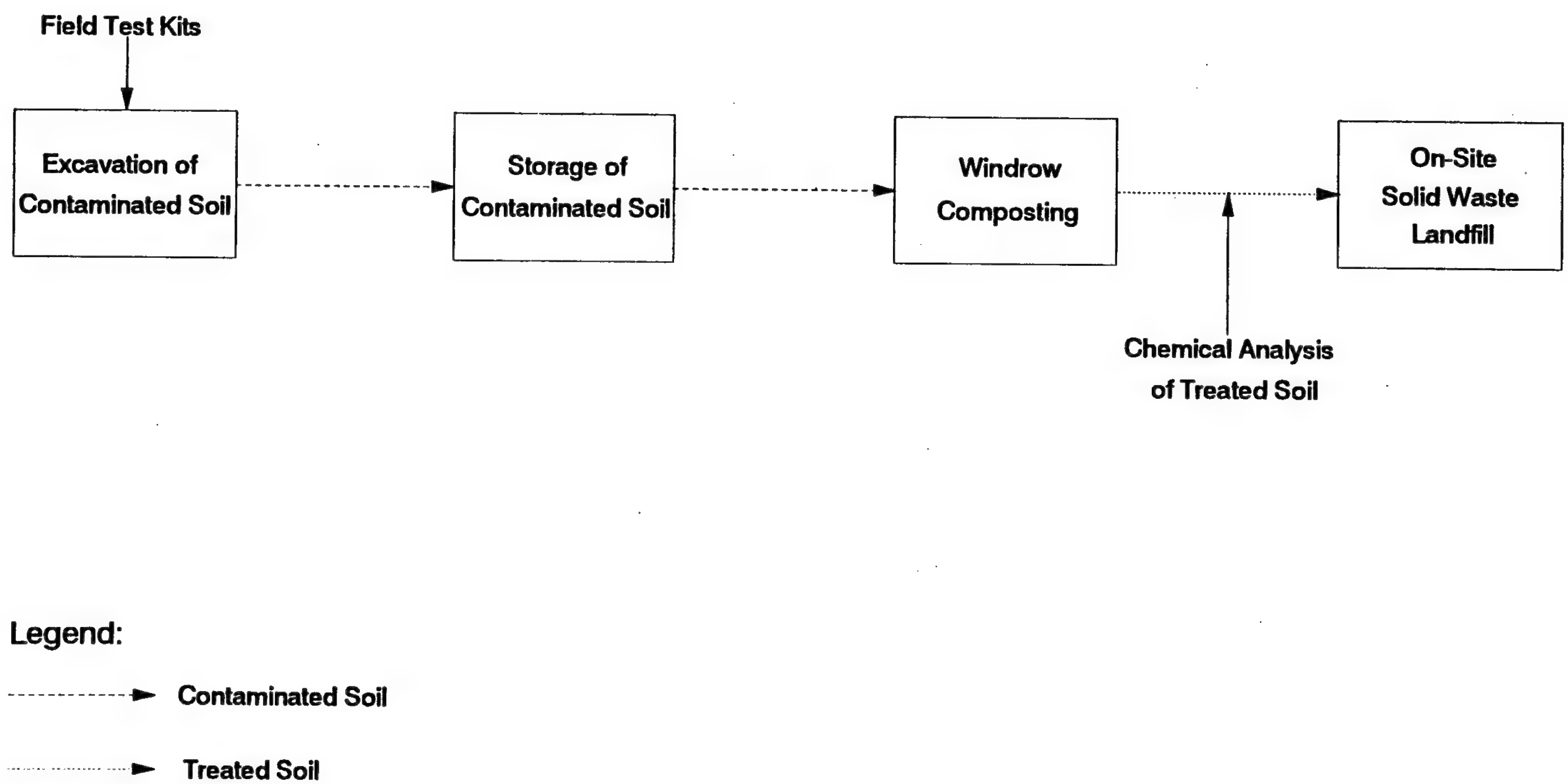

Figure 6-3
Process Flow Diagram for Excavation/Storage/Windrow Composting/On-Site Landfill

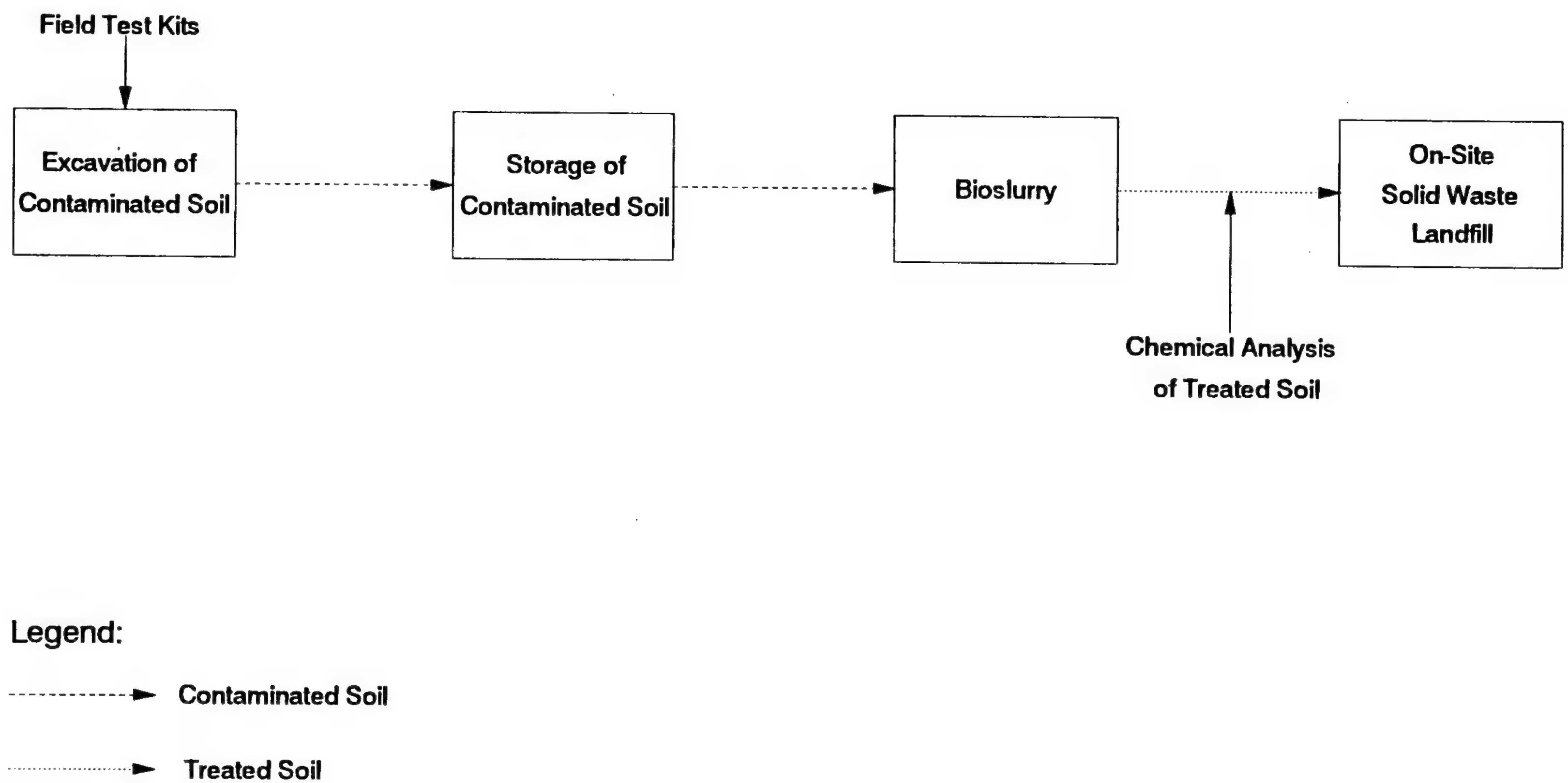

Figure 6-4
Process Flow Diagram for Excavation/Storage/Bioslurry Treatment/On-Site Landfill

be used to cover explosives-contaminated soil in areas where excavation would be uneconomical or impractical (i.e. where the stability of a building foundation would be compromised by excavation).

This alternative would also include institutional restrictions, maintenance of the existing fences, public education programs, and five-year reviews as described in Alternative B.

6.2.4.2 Excavation/Backfill. Excavation of the explosives-contaminated soil would be performed in a similar manner to Alternative C.

The volume of soil to be excavated would be based on analysis of soil samples collected during excavation. Soil analysis would be performed using field test kits for 2,4,6-TNT-related compounds and RDX-related compounds. After confirmatory sampling, the excavated section would be backfilled prior to proceeding to the next section of excavation. Soil obtained from a clean borrow area at MAAP would be used as backfill. Compaction and grading of the backfilled section would be performed by conventional equipment such as a front-end loader or bulldozer. Reseeding of the backfilled section would be performed to prevent erosion.

The clean borrow area would require site preparation before excavation by clearing and grubbing existing surface vegetation and stripping grass from the site. During clearing, grubbing, and excavation activities, dust suppression and erosion control measures would be implemented. Air monitoring stations would be positioned to ensure compliance with Tennessee Air Pollution regulations that govern particulate emissions.

6.2.4.3 Soil Storage. Storage of the explosives-contaminated soil before biological treatment would be performed in a similar manner to Alternative C.

6.2.4.4 Biological Treatment. The three biological treatment options retained for this detailed analysis are windrow composting, aerobic bioslurry treatment, and anaerobic bioslurry treatment. The following discussion presents a description of the treatment options, a summary of previous studies for each technology, and a description of the treatment system which would be used at the northern industrial areas.

<u>Treatment Goal</u>. Windrow composting, aerobic bioslurry, and anaerobic bioslurry treatment would be expected to achieve the treatment goal of 20 $\mu g/g$ (separately for 2,4,6-TNT-related compounds and RDX-related compounds). This treatment goal is based on the effective limit of the biological treatment technologies. Bioremediation is expected to reduce the concentrations of nitrobenzene and 2,4-DNT to levels low enough such that the soil would pass TCLP. The soil must also pass the Paint Filter Liquid Test in order to be disposed as a solid waste.

<u>Windrow Composting</u>. Windrow composting is a static pile method of reducing the levels of explosives compounds and the leachable toxicity of explosives-contaminated soil. In the composting system, explosives-contaminated soil would be mixed with sources of organic carbon and bulk such as wood chips, straw, and manure. The compost would be mixed using a backhoe. Once mixed, the compost would be formed into long static piles called windrows. The windrows would be turned over periodically to provide adequate mixing of the compost. Mixing would be performed using a windrow turner. Prior to full-scale operation of a windrow composting facility, studies would be performed to determine the type and fraction of amendments for the compost, mixing frequency, and duration of the treatment process. Bench- and field-scale studies have been performed at UMDA and LAAP using windrow composting on soil similar to the soil at MAAP. The data from these studies could be used to design the treatment system for the northern industrial areas.

Previous Windrow Composting Bench and Field Studies. Several bench-scale and field-scale studies have been performed using composting at UMDA and LAAP. The results of these studies indicate that composting was effective in reducing both explosives levels and the toxicity of the explosives-contaminated soil (USAEC, 1988b; USAEC, 1991b). Extensive reductions in 2,4,6-TNT, RDX, and HMX were observed during studies performed at LAAP under both mesophilic (35°C) and thermophilic (55°C) conditions. Total explosives concentrations were reduced from 16,460 μg/g and 17,870 μg/g to 326 μg/g and 74 μg/g for the mesophilic and thermophilic piles, respectively. The results of these studies indicated that higher explosives degradation rates occur under thermophilic conditions (USAEC, 1988b). During compost sampling, it was noted that there were areas of high explosives contamination within the static pile after composting. The reason for the hot spots may have been due to the lack of mixing during the studies. It was determined that mixing of the compost is required to achieve maximum reductions in explosives compounds within the compost. Mixing systems must achieve good homogeneity, handle materials with high bulk densities such as soil, and meet all safety criteria (USAEC, 1988b).

Field-scale studies were performed at UMDA (USAEC, 1991b) based on the work performed at LAAP. The objective of these studies was to increase the rate of explosives-contaminated soil processed with composting by either increasing the soil loading or increasing the explosives degradation rate. MAIV and static pile composting were the two composting methods used in this investigation. Three amendment configurations were selected for these studies: sawdust, apple pomace, potato waste, and chicken manure; alfalfa, horse feed, and horse and buffalo manure; and sawdust, apple pomace, potato waste, alfalfa, and cow manure. The results of these studies are presented in Table 6-3. The soil loading which obtained the highest explosives degradation rate was approximately 30 percent soil by weight (USAEC, 1991b). The low explosives reductions in the static pile tests were a result of mechanical problems and loss of temperature control. The static pile with 10 percent soil loading by weight was the only test with adequate temperature control, and increased explosives removal. Generally MAIV composting removed a higher percentage of explosives than the static pile. The superior performance of the MAIV tests illustrates the importance of mixing during composting. Another finding in these studies was the importance of amendment composition. The amendment mixture of alfalfa, horse feed, and horse and buffalo manure did not perform as well as the other composting mixtures. It was determined that proper selection and combination of amendment materials used in composting is essential in ensuring proper explosives removal during composting. In addition to explosives reductions during composting, preliminary toxicity tests performed on compost samples taken throughout the studies indicated a significant reduction in leachable toxicity by day 10 of the study.

More recently, field studies have been performed at UMDA to optimize composting using windrows (USAEC, 1993b). Windrow composting was chosen over other treatment methods because it was the simplest composting method in terms of equipment and operation. Mixing of the compost could be performed using a windrow turner as opposed to the more elaborate mixing system used in MAIV batch reactors. Four experiments were performed at UMDA. Tests were performed to determine the following:

- Whether thermophilic composting of the soil could be achieved;
- The optimal soil loading needed to reduce explosives levels in the soil;
- The rate and effectiveness of windrow composting; and
- The leachable toxicity reduction of explosives-contaminated soil treated with windrow composting.

Studies were performed using uncontaminated soil loadings of 10, 20, and 30 percent by volume to determine whether thermophilic composting of soil matrices could be achieved. Each windrow had a volume of approximately 30 yd^3. An amendment mixture of saw dust, wood chips, alfalfa, potato waste,

Table 6-3
UMDA Composting Studies

Composting Method	Soil Loading (% wt)	Initial 2,4,6-TNT (μg/g)	Final 2,4,6-TNT (μg/g)	2,4,6-TNT Removal	Initial RDX (μg/g)	Final RDX (μg/g)	RDX Removal	Initial HMX (μg/g)	Final HMX (μg/g)	HMX Removal
Static Pile	7%[a]	1,144	107	91%	776	213	73%	120	73	39%
Static Pile	10%[c]	3,850	41	99%	618	46	93%	307	61	80%
Static Pile	20%[a]	5,716	331	94%	1,076	902	16%	194	184	5%
Static Pile	30%[a]	7,908	174	98%	1,178	924	22%	236	210	11%
Static Pile	40%[a]	9,858	2,086	79%	1,572	1,674	NA	310	305	2%
Static Pile	80%[d]	11,320	10,640	6%	1,234	1,180	4%	243	238	2%
MAIV	10%[b]	3,126	5.6	99%	575	3.8	99%	119	6.1	95%
MAIV	25%[c]	5,208	14	99%	597	18	97%	161	51	68%
MAIV	40%[c]	6,950	209	97%	754	621	18%	456	601	NA

(Source: USAEC, 1991b)

NA = Not applicable.
a = Sawdust, apple pomace, chicken manure, and potato waste.
b = Horse manure/straw, buffalo manure, alfalfa, and horse feed.
c = Sawdust, apple pomace, potato waste, alfalfa, and cow manure.
d = Sawdust, ammonia sulfide, sodium acetate, L-arginine.

and cow and chicken manure was chosen based on previous composting studies at UMDA. Composting parameters such as temperature, pH, moisture content, and the percent oxygen were measured to determine the performance of the study. The temperature of the windrows remained between 50°C and 70°C, which is considered thermophilic conditions. Thermophilic composting was achieved in composts with soil loadings up to 30 percent by volume. The pH of the windrow increased over time, which is similar to the results of previous studies (USAEC, 1991b). The optimal moisture content of 50 to 60 percent water holding capacity was maintained by periodically applying water to the windrows. The water holding capacity is a ratio of the percent moisture of the soil to the percent moisture of the soil at saturation. In order to maintain the moisture content at an optimal level, water was added to the windrows periodically using a garden hose with a flow rate of eight gallons per minute. A total of 80 gallons of water per cubic yard of compost was applied to the windrows throughout the duration of the study. An interesting observation of this study was that approximately 1 hour after turning the windrow, the oxygen level within the windrow fell far below ambient levels of 20.9 percent by volume.

Aeration studies were performed on windrows with 30 percent soil by volume to evaluate the effects of aeration on thermophilic composting. Aeration was performed by placing slotted pipe under the windrow and applying a vacuum to the pipes which pulled air through the windrow. Over the 40-day test, the number of aerobic, anaerobic, and thermophilic bacteria decreased over time in both the aerated and unaerated windrows. Oxygen levels in the aerated windrow were maintained at approximately 15 percent. During the first 5 days of the test, the aerated windrow overheated due to increased microbial activity but leveled out to approximately the temperature in the unaerated windrow after 5 days. Studies performed on aerated and unaerated windrows using explosives-contaminated soil indicated that the unaerated windrow had a higher percent removal of HMX as compared to the aerated windrow (see Table 6-4). 2,4,6-TNT and RDX removals were similar for both studies. The results of these studies indicated that windrow composting destroys not only target explosives compounds but also extractable explosives intermediates. Table 6-5 presents the results of intermediates reduction in the windrow studies.

Toxicity and mutagenicity tests were performed on leachate extracted from samples collected over the 40-day composting studies. The extraction method used in this study was the Clean Closure Leaching Test (CCLT) method. Analytical results of the leachate indicate that a significant reduction in explosives compounds and degradation intermediates occurred in the compost leachate (see Table 6-6). During the 40-day composting studies, the concentration of intermediates increased during the first 10 days of the studies and then began to decrease by day 15. The increase in the concentration of intermediates in the leachate was due to the biotransformation of 2,4,6-TNT, and the decrease in the concentration of intermediates in the leachate was due to the transformation of the intermediates into other compounds which serve as the ultimate end products of 2,4,6-TNT biotransformation (USAEC, 1993b). It should be noted that the leachate samples from the unaerated windrow contained lower levels of explosives compounds and intermediates than the aerated windrow. Preliminary results of the toxicity tests indicated that complete detoxification occurred by day 15 of windrow composting in both the aerated and unaerated windrows (USAEC, 1993b).

Additionally, studies have been performed at UMDA to evaluate the compaction of composted materials, specifically material from windrow composting of explosives-contaminated soil (USAEC, 1993c). In this study, the volume of soil was measured before excavation (in-situ), after excavation (ex-situ), mixed compost, final compost, and buried compacted compost. The results of these studies indicated that the volume of buried compacted compost was 40 to 60 percent higher than the original in-situ volume of soil.

Table 6-4
Explosives Concentrations and Percent Removals for UMDA Windrow Composting Study

Windrow Study	TNT (μg/g)			RDX (μg/g)			HMX (μg/g)		
Time (days)	0	40	Percent Removal	0	40	Percent Removal	0	40	Percent Removal
Aerated Windrow	1,869	4	99.8	1,069	8	99.2	175	47	76.6
Unaerated Windrow	1,574	4	99.7	944	2	99.8	159	5	96.8

(Source: USAEC, 1993b)

Table 6-5
Explosives Intermediate Concentrations and Percent Removals for UMDA Windrow Composting Study

Windrow Study	2,4-D-6-NT ($\mu g/g$)			4-A-2,6-DNT ($\mu g/g$)			2,6-D-4-NT ($\mu g/g$)			2-A-4,6-DNT ($\mu g/g$)		
Time (days)	0	40	Percent Removal	0	40	Percent Removal	0	40	Percent Removal	0	40	Percent Removal
Aerated Windrow	40.09	2.54	93.7	238.89	4.81	98.0	42.44	2.54	94.0	120.83	2.11	98.3
Unaerated Windrow	34.61	2.58	92.6	219.11	3.76	98.3	37.92	2.58	93.2	127.67	2.58	98.0

(Source: USAEC, 1993b)

2,4-D-6-NT = 2,4-Diamino-6-Nitrotoluene
4-A-2,6-DNT = 4-Amino-2,6-Dinitrotoluene
2,6-D-4-NT = 2,6-Diamino-4-Nitrotoluene
2-A-4,6-DNT = 2-Amino-4,6-Dinitortoluene

Table 6-6
CCLT Leachate Data for UMDA Windrow Composting Study

Windrow Study	Day	TNT (mg/L)	RDX (mg/L)	HMX (mg/L)	2,6-D-4-NT (mg/L)	2,4-D-6-NT (mg/L)	2-A-4,6-DNT (mg/L)	4-A-2,6-DNT (mg/L)
Aerated Windrow	1	22.4	19.0	6.96	<1.10	<1.10	3.91	8.25
	40	<0.10	0.44	3.32	<0.11	0.19	<0.13	<0.10
Unaerated Windrow	1	26.5	20.2	7.52	<0.10	<1.10	5.41	11.4
	40	<0.10	<0.24	<0.19	<0.11	<0.11	<0.13	<0.10

(Source: USAEC, 1993b)

Other results of the composting pilot studies, as determined from work by Oak Ridge National Laboratory (ORNL) (Griest, et al., 1994), are as follows:

- Concentrations of aminonitroaromatic intermediates were significantly reduced after 15-40 days of composting. Most products were not identified; non-degraded explosives compounds, amino derivatives, azo compounds, carbon dioxide, and other identifiable species accounted only for a small fraction of the original loading of nitrogen compounds.

- Solvent extracts of aerated and non-aerated composts showed a reduction in mutagenicity (as determined by the Ames Test) of better than 99 percent after 40 days of composting. Weakly acidic extracts showed marked decreases in toxicity (lethality and reproduction effects using *Ceriodaphnia dubia*); most of the initial leachable toxicity was removed after 40 days of composting.

- A simulated 1000-year acid rain leaching test (modified USEPA Synthetic Precipitation Leaching Test), conducted either before or after irradiation of the composted material by ultraviolet light, indicated that less than 10 percent of the 2,4,6-TNT transformation products were leachable.

- Bacteria isolated from composted materials were shown to effectively degrade 2,4,6-TNT in laboratory tests; most of the transformation products were not identified. The preliminary results also suggested formation of high-molecular weight species of very limited solubility during biotransformation.

- Preliminary experiments to evaluate the suitability of composted materials for land application suggested that the soil composts may adversely affect germination of certain plants, but earthworms and isopods both appeared to thrive in the medium.

<u>Summary of Mechanisms Which Affect Composting Performance</u>. Available data from prior studies strongly suggest that the explosives compounds normally act as *electron acceptors* during biodegradation of compost materials by microorganisms, and are transformed into reduced intermediate species such as amines or azo compounds in the process. The reaction requires proper conditions of temperature and moisture content, as well as close proximity of three components: a source of energy (electron source) in the form of oxidizable substances that can be metabolized; a sufficient supply of appropriate organisms; and a sufficient supply of the electron acceptor (electron sink) molecules. (The presence of essential nutrients such as phosphorus and trace metals also is important). Metabolism results in growth and reproduction of the organisms, formation of metabolic and biotransformation products, and corresponding depletion of the energy source and the electron acceptor materials. This requirement to aggregate three (or four) separate materials accounts for the observations that thorough mixing is important if composting is to be effective. Mixing may be even more important for treatment of soil containing low concentrations of explosives compounds, because depletion could easily occur on a local scale.

Mixing and aeration also may play an important role in the temperature control that is necessary for optimizing the microbial growth rate. However, optimal conditions for the nitro-compounds to participate also require the absence or depletion of more aggressive oxidizers (i.e. materials with a higher oxidation-reduction potential) such as free oxygen and nitrate ions. Moderate to high concentrations of less aggressive oxidizers such as sulfate, iron(III), and manganese(IV) compounds also may compete unfavorably with the nitro-compounds during the composting process. Thus, mixing, which results in aeration of the compost, probably hinders the reduction of nitro-compounds; in fact, reduction probably does not occur until the available oxygen is locally depleted.

It is not known whether aerobic processes play a role in the ultimate degradation or fixation of reduced species formed from the nitro-compounds. It is possible that the intermediate degradation products such as aminonitrotoluenes are degraded further or fixed to the soil matrix if a change occurs from anaerobic to aerobic conditions. Although mineralization of the nitro- compounds does not appear to occur readily, aerobic conditions would favor those biotransformations that oxidize the methyl group or ring portions of the explosives compounds.

The probable mechanism for the initial biotransformation of explosives compounds in the soil favors selection of mixing equipment that minimizes the introduction of air. This analysis also favors use of water for temperature control and to encourage mixing or dispersion on the molecular level.

Windrow Composting of Explosives-Contaminated Soil at the Northern Industrial Areas. The windrow composting system that would treat the soil from the northern industrial areas would be similar to the most recent UMDA system. The proposed amendment composition would be a mixture (combined by percent volume) of saw dust (25%), alfalfa (25%), potato waste (15%), cow manure (30%), and chicken manure (5%). The area in the vicinity of MAAP is rural and agricultural, therefore, many of the amendment materials would be readily available. Crops generally grown in the Milan, TN area consist of corn, cotton, soybean, and wheat with small crops of alfalfa and sweet potato. The livestock industry near Milan, TN consists of cattle, swine, and chickens (Personal Communication, Larry Kimery, Gibson County Office, TN). The materials from these farming operations could be used as amendments for windrow composting. Additionally, a wooden pallet manufacturer located in Milan, TN could be used as a source of saw dust.

A total of four 240-foot windrows (approximately 14 feet wide and six feet high) would be formed in an enclosed building to prevent run-on from precipitation. Figure 6-5 presents the site layout for the windrow composting building. The building floor would be sloped to allow leachate to drain into a collection sump. The leachate would be tested periodically for explosives compounds, and if contaminated, it may be recycled to increase the moisture content of the windrows. For the purposes of this assessment, it is assumed that the soil would be added to the amendment mixture at 30 percent by volume. Each windrow would consist of 145 yd^3 of soil and 338 yd^3 of the amendment mixture. The soil/amendment mixture would be mixed in the treatment building using a front end loader before forming the compost into windrows.

The windrow would be turned over periodically using a windrow turner to mix the compost. Windrow turners are commercially available and have been used for composting of wastewater sludge. The turners come in a variety of sizes and consist of the following components: entrance and exit tunnels; a mixing drum; and mixing flails. As the turner drives over the windrows, the compost enters the turner through a tunnel located in the front of the turner. The tunnel directs the compost into the mixing drum. Mixing flails are metal protrusions within the drum which aid in mixing. Once mixed in the mixing drum, the compost would be reformed into windrows through the tunnel located at the rear of the windrow turner. On occasion, compost might be thrown from the windrow, but would be placed back in the windrow using either shovels or a front-end loader.

The temperature and moisture content of the soil would be monitored in order to ensure optimal treatment conditions. The temperature would be maintained in the thermophilic range between 50°C and 70°C (USAEC, 1993b). The temperature would be maintained within the thermophilic range by varying the turning frequency, amendment mixture, or compost moisture. Compost moisture would be maintained between 50 and 60 percent water holding capacity as indicated by studies performed at UMDA (USAEC, 1993b). Leachate collected in the windrow building sump or fresh water could be added to the compost piles in the event that the moisture content falls below the desired range.

The composting medium would be maintained for a period of 40 days. During the winter months, the microorganisms within the compost may biodegrade the explosives compounds at a slower rate due

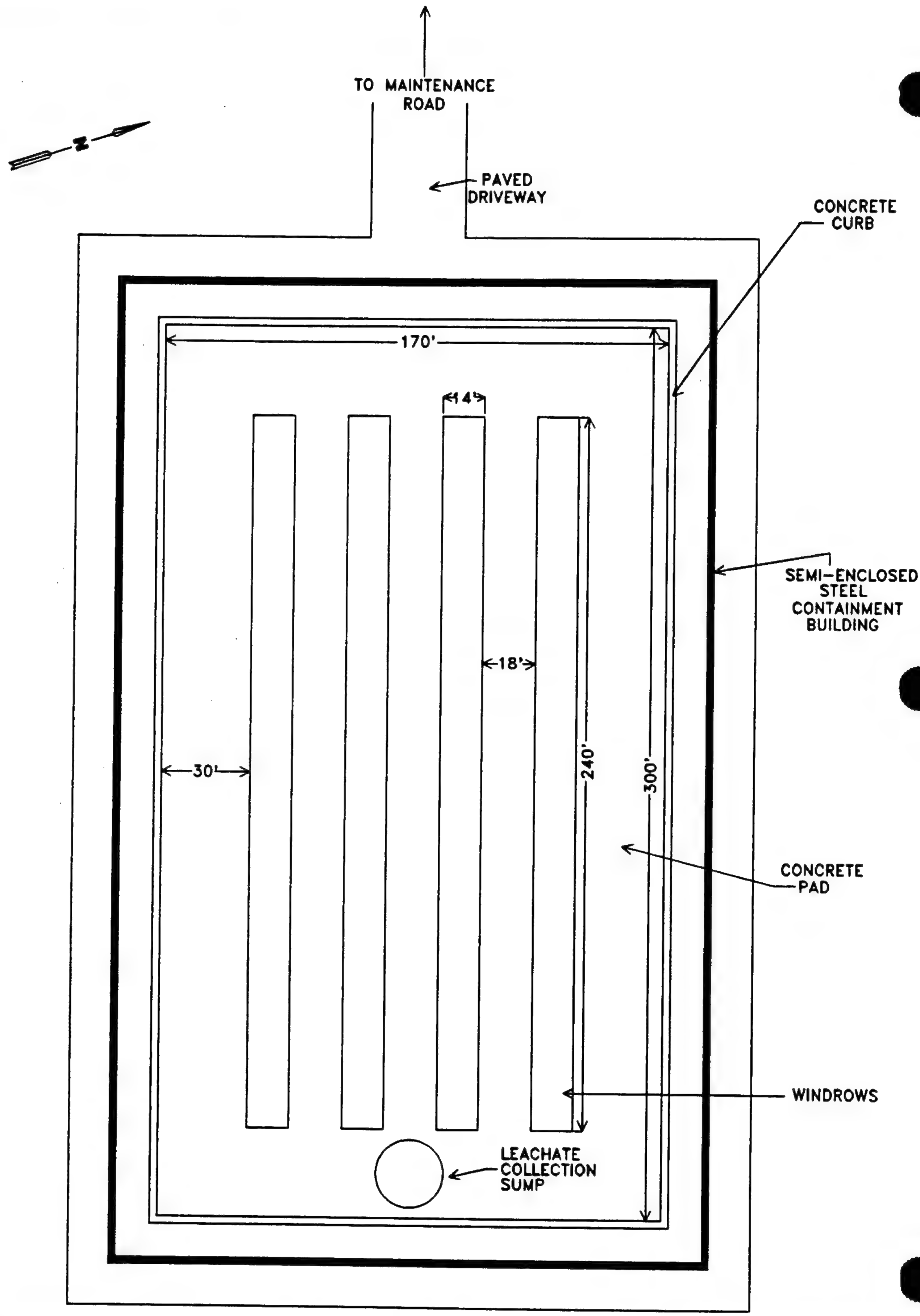

FIGURE 6-5 WINDROW COMPOSTING BUILDING SITE LAYOUT

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to the lower ambient temperatures; therefore, treatment during the winter months would require approximately 85 days. After this time period, samples of the compost would be collected and analyzed for explosives compounds, TCLP, and the Paint Filter Liquid Test. If the compost contains either 2,4,6-TNT-related compounds or RDX-related compounds above 20 $\mu g/g$ (which is the limit of the treatment technology) or fails the TCLP or Paint Filter Liquid Test, it would remain in the windrow for further treatment. Once treated, the compost would be stored until final disposal in the solid waste landfill. Approximately 1,000 tons of soil would be treated every 40 days during the warmer months and approximately 1,000 tons of soil would be treated during the winter months (approximately 85 days). The total mass of soil treated each year would be approximately 8000 tons. The amount of soil treated each year could be less if the treatment goals are not achieved.

Aerobic Bioslurry. Aerobic bioslurry treatment could be used to reduce the levels of explosives compounds and the leachable toxicity of explosives-contaminated soil by mixing the soil in a slurry of microorganisms, nutrients, and other additives. In the reactor, explosives-contaminated soil would be mixed with amendments to aid in explosives degradation. During the system start-up, studies would be performed to determine the type and fraction of amendments for the bioslurry, mixing frequency, and duration of the treatment process. Bench- and field-scale studies have been performed at Hastings Naval Ammunition Depot (NAD) in Nebraska and at Joilet Army Ammunition Plant in Illinois. The data from the studies could be used to design the treatment system for the northern industrial areas.

Previous Aerobic Bioslurry Bench and Field Studies. Aerobic bioslurry systems have been used for the remediation of soil contaminated with simple aromatics, PAHs, petroleum hydrocarbons, and pentachlorophenol. This technology has been demonstrated in bench-scale studies (5-liter reactors), pilot-scale studies (70 and 30,000 liter capacity), and full-scale systems (400,000 gallon total system capacity) (Zappi, et al., 1993). Full-scale treatment systems have demonstrated the capability to handle soil to water ratios as high as 50 percent (wt/wt), although 40 percent (wt/wt) is recommended. Recently, bench-scale studies have been performed to evaluate the biodegradation/biotransformation of explosives compounds in soil collected from the former Hastings NAD in Nebraska. The primary objective of the study was to evaluate the feasibility of bioslurry systems for the treatment of explosives-contaminated soil. The study was organized into three phases: evaluate the ability of indigenous and exotic microorganisms to degrade explosives compounds; evaluate several surfactants for improving solubilization of explosives compounds into the aqueous phase of the reactors; and determine the optimal treatment conditions for pilot- and full-scale aerobic bioslurry systems.

The first phase of the study involved determining the type of indigenous microorganisms within the soil. The most common microorganism was *pseudomonas aeruginosa*. In this study, the microorganisms were placed in a reactor with radiolabeled 2,4,6-TNT, a 2,4,6-TNT cometabolite (acetate or succinate), and nutrients (ammonia and phosphorus). The indigenous microorganisms were capable of mineralizing 15 percent of the radiolabeled 2,4,6-TNT into carbon dioxide. Unfortunately, when the study was performed using the exotic microorganisms, no 2,4,6-TNT removal occurred due to ammonia toxicity caused by excessive nutrient addition. It was recommended that the nutrient dose not exceed 20 mg/L of ammonia and 10 mg/L of phosphate. Based on the studies, it was also recommended that acetate be added to the bioslurry at approximately 1 percent on a weight per volume basis.

Several surfactants were evaluated to determine if they could improve the solubilization of explosives compounds from the soil particles into the aqueous phase of the reactors. The surfactants evaluated in the studies included: TMaz 80; SMaz 80; Alfonic 1012-60; Microplex ME 1001; Microplex ME 1300; and Tween 80. In addition, acetone, a good solvent for organic contaminants, was tested. The two best surfactants from the screening were Alfonic 1012-60 and Tween 80 at a concentration of 3 percent (wt/vol). Further tests were performed on Alfonic 1012-60 and Tween 80 to evaluate their effectiveness in extracting explosives compounds by sequential desorption. In this process, the soil was contacted four

times with a fresh solution of surfactant. In addition to solubilizing 2,4,6-TNT, a number of transformation products were also solubilized using the sequential desorption technique.

Four bench-scale bioslurry studies were performed evaluating the removal of explosives compounds from soil. The following treatment conditions were evaluated: acetate-amended; acetate- and nutrient-amended; acetate- and surfactant-amended; and acetate-, nutrient-, and surfactant-amended. The surfactant chosen for the bioslurry studies was Tween 80 based on past operational experience with this surfactant. Foaming became a problem in the studies and was controlled by an anti-foam agent commonly used in fermenter studies. The results of the studies indicated that both the acetate- and surfactant-amended reactor and the acetate-, surfactant-, and nutrient-amended reactor had the most rapid rate of 2,4,6-TNT degradation and build-up of intermediates. The addition of nutrients to the acetate- and surfactant-amended reactor increased 2,4,6-TNT and intermediate degradation. Results of these studies are presented in Table 6-7. Low levels of 2,4,6-TNT were detected in both the acetate- and surfactant-amended reactor and the acetate-, surfactant-, and nutrient-amended reactor after 7 weeks and 2,4,6-TNT was not detected in the acetate- and surfactant-amended reactor after 9 weeks. It is estimated in full-scale operation that contact times would be less than seven weeks because of the high initial 2,4,6-TNT concentrations used in the studies (18,000 mg/kg) (Zappi, et al., 1993).

Aerobic Bioslurry Treatment of Explosives-Contaminated Soil at the Northern Industrial Areas. The aerobic bioslurry treatment system would be based on the studies performed at Hastings NAD. Bioslurry reactors as large as 400,000 gallons could be used to treat the explosives-contaminated soil. The actual size of the reactors would depend on commercial availability. The total treatment time for each bioslurry batch reactor would be less than 9 weeks.

Excavated soil would be loaded into the bioslurry reactors at a soil to water ratio of 40 percent (wt/wt). Ammonia and phosphate would be the two nutrients added to the bioslurry at concentrations of 20 mg/L and 10 mg/L, respectively. These nutrient levels were determined to provide the microorganisms with the optimal environment for treating the explosives-contaminated soil. The surfactant Tween 80 would be added to the bioslurry at 3 percent by volume. The surfactant would increase the availability of the explosives compounds to the microorganisms by extracting them from the soil. Foaming would be controlled using anti-foam agents. The 2,4,6-TNT cometabolite acetate would be added to the bioslurry at a concentration of 1 percent (wt/vol). Amendments such as potato waste could be added to the bioslurry to act as a supplemental carbon source for the microorganisms.

Once the bioslurry reactor has operated through a complete cycle, the soil would be tested for 2,4,6-TNT-related compounds, RDX-related compounds, TCLP, and the Paint Filter Liquid Test. In the event that the levels of 2,4,6-TNT-related compounds and/or RDX-related compounds in the treated soil exceeded 20 μg/g (which is the limit of the treatment technology) or fails the TCLP or Paint Filter Liquid Test, the soil would remain in the bioslurry reactor for further treatment. The bioslurry would be removed from the reactor after the levels of 2,4,6-TNT-related compounds and/or RDX-related compounds fell below 20 μg/g and the treated soil passed the TCLP and Paint Filter Liquid Test. The treated soil would be dewatered before disposal using a gravity dewatering system. Once the bioslurry has been sufficiently dewatered, the treated soil would be disposed in the on-site solid waste landfill.

Anaerobic Bioslurry. The anaerobic bioslurry reactors would be similar to aerobic systems in that the levels of explosives compounds and the leachable toxicity of explosives-contaminated soil would be reduced by mixing the soil in a slurry of microorganisms, nutrients, and other additives. The difference between the two bioslurry processes is that the anaerobic bioslurry would be isolated from the outside atmosphere. In an anaerobic environment, microorganisms would biodegrade explosives compounds and their associated biodegradation products into p-cresol, methane, and carbon dioxide. In order to provide proper contact between the contaminants and the soil, it would be constantly mixed within the bioslurry reactor. The anaerobic bioslurry reactors would be designed to prevent oxygen from entering the reactor,

Table 6-7
Analytical Results of 9 Week Bioslurry Studies

Amendment Study	2,4,6-TNT ($\mu g/g$) (C_o=18,572)	RDX ($\mu g/g$) (C_o=19.36)	Tetryl ($\mu g/g$) (C_o=5.4)	1,3-DNB ($\mu g/g$) (C_o=2.65 to 3.9)	2-4 DNB ($\mu g/g$) (C_o=14.35)	1,3,5-TNB ($\mu g/g$) (C_o=30.9)	2-A-4,6-DNT ($\mu g/g$) (C_o=nd)
Acetate	2,610	ND	ND	22.06	6.42	3.35	317
Acetate/ Surfactant	ND	ND	ND	12.27	ND	ND	256
Acetate/ Nutrients	3,685	ND	23.85	7.28	5.10	2.8	154
Acetate/ Surfactants/ Nutrients	3	ND	ND	7.77	ND	1.76	393

(Source: Zappi, et al., 1993)

ND = Not present above method detection limits
C_o = Initial Concentration

while venting methane and carbon dioxide to the outside atmosphere. As with the aerobic bioslurry system, the environmental parameters such as pH, temperature, and nutrients would be monitored and optimized in the batch process to increase the biodegradation of organic contaminants. System start-up studies would be performed prior to full-scale operation of the anaerobic bioslurry reactor to determine the type and fraction of amendments for the bioslurry, mixing frequency, and duration of the treatment process. Bench- and field-scale studies have been performed under the USEPA SITE demonstration program. The data from the studies can be used to design the treatment system for the northern industrial areas.

Previous Anaerobic Bioslurry Bench and Field Studies. Anaerobic bioslurry treatment follows the same principles as aerobic bioslurry, but in the absence of oxygen. Soil and amendments are placed in a reactor at approximately 40 percent soil (wt/wt). Based on bench-scale data, the manufacturers of anaerobic bioslurry reactors have demonstrated up to 80 percent mineralization of explosives compounds. In a field demonstration under the USEPA SITE demonstration program, 2,4,6-TNT, HMX, and RDX were mineralized with low levels of biodegradation intermediates (4-amino-2,6-dinitrotoluene, 2,4-diamino-6-nitrotoluene, and p-cresol) remaining after treatment. During this study, 2,4,6-TNT levels dropped from over 1000 μg/g to below method detection limits with increasing levels of carbon dioxide. The production of carbon dioxide was assumed to be associated with the mineralization of explosives compounds.

Anaerobic Bioslurry Treatment of Explosives-Contaminated Soil at the Northern Industrial Areas. The anaerobic bioslurry treatment system would be very similar to the aerobic system, but treatment would be performed in an anaerobic environment. Soil, nutrients, amendments, and water would be added to the reactor. Once the concentration of explosives compounds has been reduced to below 20 μg/g (separately for 2,4,6-TNT-related compounds and RDX-related compounds), which is the limit of the treatment technology, the soil would then be tested using the TCLP and Paint Filter Liquid Test. If the soil passes the TCLP and Paint Filter Liquid Test, it would be disposed in the solid waste landfill.

6.2.4.5 On-Site Landfill. Treated soil would be placed in a solid waste landfill to contain the biotransformed and non-biodegraded explosives compounds of unknown toxicity which would remain in the soil. Therefore, the soil would be isolated from human and ecological receptors and would not leach contaminants to the groundwater. The on-site landfill would be designed to comply with all applicable TDEC and USEPA regulations and permitting procedures for solid waste landfills. Access and use would be controlled by installing a fence around the perimeter of the landfill. Gates would be installed to allow limited access of personnel and machinery into and out of the landfill area. Trained personnel would be on duty at all times to assure operational compliance and prevent unauthorized entry. Operating equipment for the landfill would include excavation, spreading, and compaction equipment. A thirty-day supply of cover material would be available to cover the treated soil. Dust control measures such as water application would be used to reduce health and safety hazards to personnel working on site. The design of the landfill would include a liner, and final closure would incorporate an impermeable cap over the landfill.

Final design of the landfill would be completed after the site location has been selected. Further characterization work would include site surveying and geotechnical data relevant to requirements for compaction and stabilization of the site. Evaluations of the subsurface would be based on soil borings and other subsurface investigation methods. Information would include soil descriptions, groundwater levels, groundwater flow maps, and a description of the groundwater recharge. In addition, the following information would be included in the evaluation: the location of all existing and abandoned wells; the location of any natural springs within a 1-mile radius; and the location of any public water supply wells within a 2-mile radius. Buffer zones would be established for the location of the landfill in accordance with State of Tennessee regulations. The landfill would be at least 100 feet from all property lines; 500 feet from all residences; 500 feet downgradient from drinking water wells; 200 feet from surface waters; and no construction activities would be performed within 50 feet of the property line.

Prior to construction, the site would be prepared for installation of the solid waste landfill. Site preparation at the solid waste landfill would include the following:

- Establishment of proper site security. Fences may need to be moved to allow access for equipment and materials that would be used in constructing the landfill.

- Clearing vegetation from the site. The cost estimate for this alternative assumes that any trees or brush removed from the site would be disposed at the OBG at MAAP. Grass and topsoil would be reutilized in the final cap cover.

- Establishment of support facilities and a staging area. This would include constructing access roads, equipment and materials staging and stockpile areas, field offices, and decontamination facilities.

- Monitoring well installation. One well would be installed upgradient and two wells would be installed downgradient of the landfill.

Waste handling would include all activities associated with the treated soil disposed in the landfill. These activities would include the dumping, compaction, and covering of the treated soil. Treated soil handling would be performed in the smallest area possible in order to control the amount of treated soil exposed to the atmosphere. The treated soil would be covered daily to minimize the run-on of precipitation and run-off. Temporary erosion controls such as silt fences would be used to minimize erosion of the temporary cover. Particulate releases would be kept to a minimum by spraying the site with water and covering it if needed.

A liner system for the landfill would be constructed of compacted clay, which would be obtained from clean areas at MAAP. The liner would extend to all areas which would be in contact with the treated soil. The performance standards for the liner would be a minimum compacted thickness of 3 feet, capable of achieving a maximum hydraulic conductivity of 10^{-7}cm/s. Cement or bentonite could be used to improve the performance of the liner as long as the liner thickness would not be less than 2 feet. Care would be taken to ensure uniform compaction of the liner material.

An impermeable cap would be installed only after all the excavated soil from the northern industrial areas was treated and the final grade of the landfill had been reached. The cap for the landfill would provide long-term minimization of liquids migration through the solid waste landfill. The cap would function with little maintenance, promote drainage off the landfill, and accommodate settling and subsidence so that the cap integrity would be maintained. The permeability of the cap would be less than or equal to that of the liner system. Grading of the landfill would be designed to minimize run-on to the landfill, maximize precipitation drainage off the landfill, and minimize cap erosion. The surface drainage system would be designed so that the adjacent land is not adversely impacted.

The first phase of cap construction would consist of grading of the site, which would level the site and provide a foundation on which to construct the cap. The compacted treated soil would act as a level, stable base for the cap.

Above the treated soil, approximately 13,000 cubic yards of clay would be placed in a 30-inch thick layer. Clay for the cap would be obtained from a clean area at MAAP. This clay layer would require 90 percent compaction. On top of this, the uppermost soil layer would be installed. This layer would consist of 8 inches of uncompacted topsoil planted with grass or other durable vegetation. The purpose of this upper soil and vegetation layer would be to protect the underlying clay layer, to prevent surface erosion of the cap with minimum maintenance, and to increase evapotranspiration from the surface of the cap, thereby reducing infiltration. Vegetation for the cap would be durable but would not have deeply

penetrating root systems. Erosion control measures such as silt fences would also prevent loss of topsoil. The top slope of the cap would be a minimum of 2 percent to allow for proper drainage.

Post-closure care of the landfill and cap would be performed for a minimum of 30 years after final closure. The final contours and drainage of the cap and surrounding area would be maintained. The vegetated cover would be maintained and mowed to prevent undermining of the cap due to erosion. The cap would be inspected for differential settling, which could cause breaching of the impermeable layers. Contingency plans for responding to subsidence problems would be devised as part of a long-term maintenance plan for the cap. In addition, groundwater would be monitored for the migration of leachate from the landfill.

A post-closure groundwater monitoring program would be implemented to determine if contaminants from the landfill are entering the groundwater. Groundwater samples collected from the upgradient monitoring well would represent the quality of groundwater not affected by the landfill facility drainage. Groundwater samples collected from the two downgradient wells would represent groundwater quality passing beneath the landfill area. The groundwater monitoring program would include procedures for sample collection, preservation, shipment, and analysis. The compounds to be monitored in the groundwater would be determined during the permitting process of the landfill. Samples would be collected quarterly for the first year and every six months thereafter, until the end of the post-closure monitoring period. A record would be maintained of all monitoring results.

6.2.4.6 Optional Engineered Caps. The use and construction of the optional engineered caps would be performed in a similar manner to Alternative C.

6.2.4.7 Overall Protection of Human Health and the Environment. The excavation, biological treatment, and on-site landfilling portion of this alternative would provide a high level of protection to human health and the environment by removing the soil containing explosives compounds above the risk-based remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds in the northern industrial areas; reduce the levels of explosives compounds and the leachable toxicity of the soil through treatment; and disposing of the treated soil in an on-site landfill.

The optional engineered caps would also reduce the risk levels posed by the explosives-contaminated soil at the northern industrial areas where excavation is uneconomical or impractical. Capping areas of explosives-contaminated surface soil would prevent potential dermal absorption and incidental ingestion exposures, and leaching of explosives compounds to groundwater. After construction is complete, workers at the facility and potential future residents would not be exposed to the explosives-contaminated soil because the engineered caps would provide a physical barrier to the contaminants, and the caps would provide an impermeable barrier preventing leaching of the explosives compounds which would protect groundwater.

During the remediation activities, short-term protection of public health would be adequately protected through access restrictions and the minimization of airborne emissions. Personnel working at the excavation site would be equipped with proper personal protection equipment to minimize potential exposure.

6.2.4.8 Compliance with ARARs. Section 3.0 of this document has identified the ARARs for the northern industrial areas. As indicated in Section 3.2, there are no chemical-specific ARARs defined for explosives compounds in soil.

All components of this alternative would be in compliance with action-specific ARARs. Biological treatment, if properly implemented and performed within the established operating parameters would allow the treated soil to pass TCLP and the Paint Filter Liquid Test. Disposal of the treated soil in the solid

waste landfill would be conducted within solid waste regulations. Action-specific ARARs which apply to landfill and surface impoundment closures would be met by the optional engineered caps. Groundwater monitoring for the optional engineered caps would be performed under a separate operable unit to evaluate groundwater protection.

Excavation, biological treatment, and disposal in the on-site solid waste landfill and the optional engineered caps would be expected to comply with the State of Tennessee regulations concerning fugitive dust. Non-point source emissions of explosives-contaminated particulates by wind and stormwater erosion that could be generated during clearing, grubbing, and earthwork would be controlled by water spray and erosion controls. These controls would ensure compliance with Tennessee Air Pollution Control regulations concerning particulate emissions (Rule 1200-3-7.03(2)) and the substantive requirements of the Tennessee Water Pollution Control Regulations general stormwater permit program for construction activities (Rule 1200-4-10.05). Based on the analyses, this alternative would be expected to comply with all ARARs and TBCs. There are no location-specific ARARs which would prevent the use of this alternative.

6.2.4.9 Long-Term Effectiveness and Permanence. The excavation, biological treatment, and on-site solid waste landfill proposed in this alternative would provide long-term effectiveness and permanence. Reduction in the levels of explosives compounds and the leachable toxicity of the excavated soil would be achieved by biological treatment. Biological treatment has been demonstrated to be effective in reducing the levels of explosives compounds in contaminated soil at other Army ammunition plants. Biological treatment followed by disposal of the treated soil in a solid waste landfill would be a permanent solution to the exposure risks to workers and would protect the groundwater quality at the northern industrial areas.

If properly maintained, the optional engineered caps would provide long-term isolation of explosives-contaminated surface soil, and would prevent contaminant leaching to groundwater. Human exposures to surface soil via direct contact and incidental ingestion would be eliminated and groundwater would be protected. Additionally, the concentration of explosives compounds in the soil under the optional engineered caps may be reduced over many years by intrinsic biodegradation.

Access controls that are already in place, such as the existing fences, would require maintenance. The optional engineered caps would require periodic maintenance to ensure their impermeability. Erosion control and mowing would both be required for the on-site solid waste landfill.

6.2.4.10 Reduction of Toxicity, Mobility or Volume Through Treatment. The excavation, biological treatment, and on-site solid waste landfill proposed in this alternative would remove the explosives concentrations in the soil to below the risk-based remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds at the northern industrial areas. The excavated soil would be treated using biological treatment to reduce the levels of explosives compounds and the leachable toxicity, and disposed in an on-site landfill to reduce the mobility of contaminants. The volume of the contaminants would be reduced, and the biological treatment would bind the degradation products into the soil matrix.

The optional engineered caps would not include a treatment process, but would rely on containment only. No contaminants would be treated or destroyed; therefore, toxicity and volume of the explosives-contaminated soil would not be reduced. However, the engineered caps would provide some reduction of contaminant mobility. All surface transport pathways (i.e. wind erosion and surface water runoff) would be eliminated, and vertical migration to groundwater would be reduced.

6.2.4.11 Short-Term Effectiveness. Short-term risks to workers, the public, and the environment during construction and implementation of this alternative are expected to be minimal. Access restrictions

would be effective in minimizing risks in the short term. Personnel working at the excavation site, storage and biological treatment site, and solid waste landfill would be equipped with proper personal protection equipment to minimize potential exposure.

Implementation of this alternative, from design to landfill closure, would require approximately 75 months. The design, review, and procurement of the equipment and materials for the biological treatment system and the solid waste landfill would require approximately 12 months. Complete remediation of the soil containing explosives compounds above risk-based remediation goals from the northern industrial areas would be completed in approximately 57 months. Installation of the landfill cap would require less than 6 months.

6.2.4.12 Implementability. Biological treatment has been demonstrated to effectively treat explosives-contaminated soil at other Army ammunition plants. Windrow composting would be easily implementable because all equipment required for treatment is commercially available and the technology has been implemented at other Army ammunition plants to remediate soil contaminated with explosives compounds. On the other hand, bioslurry treatment reactors, although commercially available, have only demonstrated successful treatment of soil contaminated with explosives compounds using bench- and pilot-scale studies. Full-scale treatment of soil contaminated with explosives compounds has not been performed; therefore, bioslurry treatment would not be as implementable as windrow composting.

Operation of the excavation, biological treatment, and landfilling operations would require supervision eight-hours per day. The range of operating parameters that meet the risk-based remediation goals would be established during system start-up. Personnel required per shift for the biological treatment system would include a loader, treatment system operator, stand-by maintenance person, and supervisor. Additional personnel would be required for soil testing, and other site work.

Utility requirements for the biological treatment system would include electricity, water, and fuel for the heavy equipment. Monitoring of the soil characteristics before and after treatment would be required.

Capping the explosives-contaminated surface soil with the optional engineered caps in areas where excavation would be uneconomical or impractical would be relatively easy to implement. Gravel, asphalt, and erosion control netting are commercially available. All required equipment for earthwork and asphalt paving is also commercially available, and would be provided by the construction contractor.

Additional actions, such as repair to the asphalt, would be relatively simple to implement. Periodic monitoring and maintenance would include visual inspection of the individual engineered caps to ensure they are still intact, and to evaluate whether erosion controls are functioning properly.

Five-year reviews would be required as part of the long-term monitoring program because residual contamination would remain on site. The tasks associated with coordinating the management of this alternative would be feasible and implementable.

6.2.4.13 Cost. A detailed cost estimate is presented in Appendix B for the excavation, biological treatment, on-site landfilling, and optional capping of explosives-contaminated soil. Table 6-8 summarizes cost estimates for excavation, windrow composting, and disposal in a solid waste landfill. Table 6-9 summarizes cost estimates for excavation, bioslurry treatment, and disposal in a solid waste landfill.

Table 6-8
Cost Estimate for Alternative D: Excavation/Storage/Windrow Composting/On-Site Landfill

ITEM		QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years,5%	Present Worth of Annual Costs 30 years, 10%
I. ADMINISTRATIVE ACTIONS						
1. Institutional Restrictions (a)			$0	$1,000	$15,000	$9,000
2. Public Education Program (b)			$20,000	$2,000	$31,000	$19,000
3. Program Oversight (c)				$25,000	$384,000	$236,000
Subtotal:			$20,000	$28,000	$430,000	$264,000
II. GENERAL ACTION/ SITE PREPARATION						
1. Roadways (d)			$14,000			
2. Contaminated Soil Excavation and Hauling (e)			$643,000			
3. Backfill Excavation, Hauling, and Placement (f)			$342,000			
4. Treated Soil to Landfill, Backfill, Compaction (g)			$441,000			
5. Landfill Liner (h)			$147,000			
6. Landfill Cap (i)			$163,000			
7. Optional Engineered Caps (j)			$19,000			
Subtotal:			$1,770,000	$0		
III. WINDROW COMPOSTING OPERATION						
1. Windrow Composting Facility ($211/ton) (k)		38,000 tons	$8,020,000			
Subtotal:			$8,020,000			
IV. LONG–TERM MONITORING, REVIEW, & MAINTENANCE						
1. Landfill Cap and Optional Engineered Cap Maintenance				$1,000	$15,000	$9,000
2. Groundwater Monitoring (l)			$30,000	$3,000	$46,000	$28,000
3. Five–Year Reviews ($15,000 ea)		6 reports		$3,000	$46,000	$28,000
Subtotal:			$30,000	$7,000	$107,000	$65,000
SUBTOTAL (I, II, III and IV)			$9,840,000	$35,000	$537,000	$329,000
V. ADDITIONAL SYSTEM COSTS (m)						
1. Health and Safety	10% of Capital subtotal		$984,000			
2. Bid Contingency	15% of Capital subtotal		$1,480,000			
3. Scope Contingency	15% of Capital subtotal		$1,480,000			
	25% of Annual subtotal			$9,000	$138,000	$85,000
Subtotal:			$3,940,000	$9,000	$138,000	$85,000
CONSTRUCTION SUBTOTAL (I, II, III, IV and V)			$13,800,000	$44,000	$675,000	$414,000
VI. IMPLEMENTATION COST						
1. Eng. Services During Construction (n)	15% of System subtotal		$1,200,000			
2. Engineering & Design (o)	10% of System subtotal		$802,000			
3. Permitting/Coordination/Legal (p)			$25,000			
Subtotal:			$2,030,000			
A. TOTAL CAPITAL COSTS			$15,800,000			
B. TOTAL ANNUAL COSTS				$44,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS					$675,000	$414,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)					$16,500,000	$16,200,000

Table 6-8 (continued)
Cost Estimate for Alternative D: Excavation/Storage/Windrow Composting/On-Site Landfill

NOTES AND ASSUMPTIONS

(a) – Includes maintenance of the fences around the northern industrial areas. Institutional restrictions would limit land use to industrial.
(b) – Includes increased public awareness of hazards through press releases, presentations, and posting of signs.
(c) – Costs include the annual salary of one part time program oversight manager. Costs do not include governmant oversight of this task.
(d) – A 24–foot wide roadway will allow access to the windrow composting facility.
(e) – Excavation includes removing the top 2" of topsoil and vegetation, excavating to a maximum depth of 10 feet, performing on–site screening to determine the extent of contamination, and lab confirmation of screening results.
(f) – Backfill will be excavated from a clean area at MAAP which will ultimately serve as the on–site landfill. Soil will be hauled to the areas where contaminated soil was excavated. Backfilled areas will be reseeded.
(g) – Treated soil will be disposed in the on–site landfill formed during excavation of the clean soil.
(h) – The liner consists of a 3–foot layer of compacted clay.
(i) – The landfill cap consists of a 30–inch layer of compacted clay. Topsoil and vegetation will prevent erosion.
(j) – A 3–inch layer of asphalt over a 6–inch layer of gravel will be placed on soil with explosives levels above the risk–based remediation goals in areas where excavation is impractical or uneconomical.
(k) – Treatment costs include earth moving equipment, windrow turner, site work, drainage, buildings, off–site analytics, and power requirements.
(l) – Cost includes installation and sampling of one upgradient monitoring well and two downgradient monitoring wells.
(m) – The scope and bid contingencies for the biological treatment of soil would generally be high due to the number of unknowns, particularly the time required to treat the soil and the amount of amendment material required. The O&M contingency is higher than the capital contingency because the O&M cost estimates for the optional engineered caps may change based on the number of caps placed. Additionally, groundwater monitoring O&M costs may change if more stringent monitoring is required.
(n) – Engineering services during construction would be high because of the composting facility, landfill, and optional engineered cap construction.
(o) – Engineering and design costs would be high due to the design of the composting facility, landfill, and optional engineered caps.
(p) – Cost includes permit application process and/or coordination with State/Federal officials regarding disposal of treated soil.

Table 6-9
Cost Estimate for Alternative D: Excavation/Storage/Bioslurry Treatment/On-Site Landfill

ITEM		QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years,5%	Present Worth of Annual Costs 30 years, 10%
I. ADMINISTRATIVE ACTIONS						
1. Institutional Restrictions (a)			$0	$1,000	$15,000	$9,000
2. Public Education Program (b)			$20,000	$2,000	$31,000	$19,000
3. Program Oversight (c)				$25,000	$384,000	$236,000
Subtotal:			$20,000	$28,000	$430,000	$264,000
II. GENERAL ACTION/ SITE PREPARATION						
1. Roadways (d)			$14,000			
2. Contaminated Soil Excavation and Hauling (e)			$643,000			
3. Backfill Excavation, Hauling, and Placement (f)			$327,000			
4. Treated Soil to Landfill, Backfill, Compaction (g)			$385,000			
5. Landfill Liner (h)			$126,000			
6. Landfill Cap (i)			$136,000			
7. Optional Engineered Caps (j)			$19,000			
Subtotal:			$1,850,000	$0		
III. BIOSLURRY TREATMENT SYSTEM OPERATION						
1. Bioslurry Treatment Facility (Estimated at $250/ton) (k)		38,000 tons	$9,500,000			
Subtotal:			$9,500,000			
IV. LONG-TERM MONITORING, REVIEW, & MAINTENANCE						
1. Landfill Cap and Optional Engineered Cap Maintenance				$1,000	$15,000	$9,000
2. Groundwater Monitoring (l)			$30,000	$3,000	$46,000	$28,000
3. Five-Year Reviews ($15,000 ea)		6 reports		$3,000	$46,000	$28,000
Subtotal:			$30,000	$7,000	$107,000	$65,000
SUBTOTAL (I, II, III and IV)			$11,200,000	$35,000	$537,000	$329,000
V. ADDITIONAL SYSTEM COSTS (m)						
1. Health and Safety	10% of Capital subtotal		$1,120,000			
2. Bid Contingency	15% of Capital subtotal		$1,680,000			
3. Scope Contingency	15% of Capital subtotal		$1,680,000			
	25% of Annual subtotal			$9,000	$138,000	$85,000
Subtotal:			$4,480,000	$9,000	$138,000	$85,000
CONSTRUCTION SUBTOTAL (I, II, III, IV and V)			$15,700,000	$44,000	$675,000	$414,000
VI. IMPLEMENTATION COST						
1. Eng. Services During Construction (n)	15% of System subtotal		$1,430,000			
2. Engineering & Design (o)	10% of System subtotal		$950,000			
3. Permitting/Coordination/Legal (p)			$25,000			
Subtotal:			$2,410,000			
A. TOTAL CAPITAL COSTS			$18,100,000			
B. TOTAL ANNUAL COSTS				$44,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS					$675,000	$414,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)					$18,800,000	$18,500,000

Table 6-9 (continued)
Cost Estimate for Alternative D: Excavation/Storage/Bioslurry Treatment/On-Site Landfill

NOTES AND ASSUMPTIONS

(a) – Includes maintenance of the fences around the northern industrial areas. Institutional restrictions would limit land use to industrial.
(b) – Includes increased public awareness of hazards through press releases, presentations, and posting of signs.
(c) – Costs include the annual salary of one part time program oversight manager. Costs do not include government oversight of this task.
(d) – A 24–foot wide roadway will allow access to the bioslurry treatment area.
(e) – Excavation includes removing the top 2" of topsoil and vegetation, excavating to a maximum depth of 10 feet, performing on–site screening to determine the extent of contamination, and lab confirmation of screening results.
(f) – Backfill will be excavated from a clean area at MAAP which will ultimately serve as the on–site landfill. Soil will be hauled to areas where contaminated soil was excavated. Backfilled areas will be reseeded.
(g) – Treated soil will be disposed in the on–site landfill formed during excavation of the clean soil.
(h) – The liner consists of a 3–foot layer of compacted clay.
(i) – The landfill cap consists of a 30–inch layer of compacted clay. Topsoil and vegetation will prevent erosion.
(j) – A 3–inch layer of asphalt over a 6–inch layer of gravel will be placed on soil with explosives levels above the risk–based remediation goals in areas where excavation is impractical or uneconomical.
(k) – Treatment costs include earth moving equipment, bioslurry reactors, site work, drainage, buildings, off–site analytics, and power requirements.
(l) – Cost includes installation and sampling of one upgradient monitoring well and two downgradient monitoring wells.
(m) – The scope and bid contingencies for the biological treatment of soil are generally high due to the number of unknowns, particularly the time required to treat the soil and the amount of amendment material required. The O&M contingency is higher than the capital contingency because the O&M cost estimate for the optional engineered caps may change based on the number of caps placed. Additionally, groundwater monitoring O&M costs may change if more stringent monitoring is required.
(n) – Engineering services during construction would be high because of the compost facility, landfill, and optional engineered cap construction.
(o) – Engineering and design costs would be high due to the design of the compost facility, landfill, and optional engineered caps.
(p) – Cost includes permit application process and/or coordination with State/Federal officials regarding disposal of treated soil.

Capital costs included in the alternative are site preparation, mobilization, set-up, and start-up testing costs. The total present worth for windrow composting as the biological treatment system is estimated to be $16,500,000 (5% discount rate), including capital costs of $15,800,000 and annual O&M expenditures of $44,000. The total present worth for bioslurry treatment as the biological treatment system is estimated to be $18,800,000 (5% discount rate), including capital costs of $18,100,000 and annual O&M expenditures of $44,000. These costs are preliminary and are subject to change. Initial costs are based on vendor information and generic unit costs.

7.0 COMPARISON OF REMEDIAL ALTERNATIVES

The detailed evaluation performed in Section 6 discussed the degree to which each remedial alternative would satisfy the evaluation criteria. To aid in identifying and assessing relative strengths and weaknesses between the remediation alternatives, this section provides a comparative analysis of alternatives. As previously discussed, the alternatives are as follows:

- Alternative A, No Action
- Alternative B, Limited Action
- Alternative C, Excavation/Storage/Incineration/Backfill
- Alternative D, Excavation/Storage/Biological Treatment/On-Site Landfill

These four alternatives are compared to highlight the differences between the alternatives, and determine their relative value in meeting seven of the nine criteria for the detailed evaluation of alternatives.

7.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Because current levels of contamination pose unacceptable levels of human health and ecological risk, Alternative A, No Action, would not meet this criterion because no actions are taken to eliminate, reduce or control exposure pathways. The threshold criterion of protection of human health and the environment would not be achieved by Alternative A.

Alternative B, Limited Action, provides some additional protection from contaminated surface soil by implementing and maintaining restrictions such as site security and fencing, which both limit site access and exposure. Although actions are taken to prevent access to areas of contaminated soil, nothing would be done to protect groundwater quality; therefore, Alternative B would not be protective of human health and the environment.

Alternatives C and D provide additional protection of human health and the environment by removing soil containing explosives compounds above risk-based remedial action objective of 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds. Alternatives C and D would remove contaminated surface soil to a maximum depth of 10 feet and treat the soil with incineration and biological treatment, respectively. Alternatives C and D both provide protection of human health and the environment by eliminating the surface soil exposure pathway and providing protection to the groundwater. Long-term maintenance of the landfill cap under Alternative D would be required. The optional engineered caps under Alternatives C and D would provide a physical barrier to the contaminants, and the caps would provide an impermeable barrier preventing leaching of the explosives compounds, which would protect groundwater. Long-term maintenance of the optional engineered caps would also be required.

7.2 COMPLIANCE WITH ARARS

Compliance with ARARs is a threshold criterion which must be met by the proposed remedial action. There are no promulgated standards for levels of explosives compounds in soil. Therefore, chemical specific ARARs do not apply to Alternatives A, B, C, or D. Because no remedial activities would be implemented under the Alternatives A and B, location-specific and action-specific ARARs also do not apply. Alternatives C and D involve further actions to eliminate the exposure to explosives compounds in contaminated soil above risk-based levels. These actions could be performed in compliance with the

action- and location-specific ARARs as identified in Section 3. These alternatives provide protection to workers and long-term protection of groundwater.

7.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Alternatives A and B would not provide long-term effectiveness and permanence. Both of these alternatives would not reduce the risk posed to workers or provide protection of groundwater above risk-based levels.

Alternatives C and D would provide long-term effective and permanent protection by removing and treating soil with explosives concentrations above the risk-based remedial action objective of 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds, destroying the explosives compounds in the soil by incineration (Alternative C), or placing the soil treated by biological treatment in a solid waste landfill and isolating the biologically treated soil using institutional controls (maintenance of site fencing) (Alternative D). The worker and ecological receptor exposure pathway would be eliminated using these alternatives, and groundwater quality would be protected.

Alternative C would incorporate incineration as the treatment method to provide the greatest degree of long-term effectiveness and permanence. Incineration could achieve the irreversible destruction of greater than 99.99 percent of the explosives compounds in the excavated soil. The treated soil would be backfilled, covered with topsoil, and revegetated.

Alternative D would incorporate either windrow composting or bioslurry treatment as the treatment method to reduce the concentrations of explosives compounds and the leachable toxicity of the excavated soil. The treated soil would be disposed in an on-site solid waste landfill in order to contain the biotransformed and non-biodegradable explosives compounds of unknown toxicity which would remain in the treated soil; therefore, Alternative D would provide permanent reduction in risk to workers and would protect groundwater quality.

The optional engineered caps proposed under Alternatives C and D would provide long-term isolation of explosives-contaminated soil, and would prevent contaminant leaching to groundwater. Human exposures to surface soil via direct contact and incidental ingestion would be eliminated and groundwater would be protected.

7.4 REDUCTION OF TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT

Alternatives A and B would not provide any reduction of toxicity, mobility, or volume of the contaminants because removal or treatment of the contaminated soil would not be components of these alternatives.

Alternative C would involve excavation of the soil containing explosives compounds at concentrations higher than the risk-based remedial action objective of 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds. All explosives compounds in the excavated soil from the northern industrial areas would be destroyed by incineration thereby reducing the toxicity, mobility, and volume of contaminants.

Alternative D would involve excavation of the soil containing explosives compounds at concentrations higher than the risk-based remedial action objective of 25 $\mu g/g$ for 2,4,6-TNT-related compounds and 10 $\mu g/g$ for RDX-related compounds. The concentration of explosives compounds and the leachable toxicity of the excavated soil would be reduced using either windrow composting or

bioslurry treatment. The volume of the contaminants would be reduced, and the biological treatment would bind the degradation products into the soil matrix. The excavated soil would be disposed in an on-site solid waste landfill, thus minimizing the mobility of the contaminants and their associated biodegradation byproducts.

The statutory preference for treatment as a remedial method would not be satisfied by the optional engineered caps proposed for Alternatives C and D. All soil that is presently contaminated with explosives compounds would remain on site under the optional engineered caps, with explosives levels unchanged except for intrinsic biodegradation.

7.5 SHORT-TERM EFFECTIVENESS

Short-term protection of the public, workers, or the environment would be met by Alternatives A and B because no remedial actions would be implemented at the northern industrial areas. Alternatives C and D would each provide for short-term protection of the public, workers, and the environment during implementation. The use of proper dust suppressant measures would control windblown emissions of contaminated dust to protect the community and on-site workers. Proper personal protective equipment would be required for site workers. Sediment and erosion control would be provided to protect the environment.

The length of time which would be required to implement the remediation alternatives follow in increasing order: Alternative B, Alternative C, and Alternative D. Alternative B, the Limited Action alternative, could be implemented in 1 year. Alternative C would require approximately 12 months to design and procure materials for excavation and thermal treatment and approximately 12 months to treat the soil. Alternative D would require approximately 12 months to design and procure all necessary equipment for excavation and biological treatment and approximately 5 years to treat the excavated soil from the northern industrial areas. Alternative D would require less than 6 months to install the impermeable cap on the solid waste landfill.

7.6 IMPLEMENTABILITY

Alternatives A and B would be the most easily implemented. Alternative A would require no change in existing controls, and nearly all components of Alternative B are already in place.

Alternatives C and D would involve excavation, treatment, and disposal of soil containing explosives compounds above risk-based levels. The equipment and materials required for the optional engineered caps proposed for Alternatives C and D are commercially available. Incineration technology selected for Alternative C has been demonstrated to be easily implementable for the remediation of explosives-contaminated soil at other sites. The reliability of rotary kiln incineration technology is quite high; typically, incinerators treat soil approximately 80 percent of the time with 20 percent downtime for periodic maintenance.

Alternative D would incorporate the use of either windrow composting or bioslurry treatment to reduce the leachable toxicity of the excavated soil. Windrow composting would be easily implementable because all equipment required for treatment is commercially available, and the technology has been successfully implemented at other Army ammunition plants to remediate soil contaminated with explosives compounds. On the other hand, bioslurry treatment reactors, although commercially available, have only demonstrated successful treatment of soil contaminated with explosives compounds using bench- and pilot-scale studies. Full-scale treatment of soil contaminated with explosives compounds has not been performed; therefore, bioslurry treatment would not be as implementable as windrow composting.

7.7 COST

Table 7-1 provides a comparison of the costs of the remediation alternatives. Total capital and annual costs and present worth (discount rate of 5 percent) for each alternative are presented. The progression of total present worth from the least expensive to the most expensive alternative is: Alternative B, Alternative D, and Alternative C. Alternative C would be more costly than Alternative D because it would use rotary kiln incineration to treat the soil instead of biological treatment. Within Alternative D, bioslurry treatment would be more expensive that windrow composting because of the more elaborate treatment and mixing systems which would be used in the bioslurry reactor. The landfill for Alternative D is more extensive and costly than the backfilling and topsoil cover in Alternative C because of the additional landfill liner and cap.

7.8 SUMMARY OF DETAILED EVALUATION

The following is a brief summary of the evaluated alternatives (refer to Table 7-2):

- Alternatives A and B would not be protective of human health and the environment. Therefore, these alternatives would be eliminated from consideration.

- Alternatives C and D would remove soil contaminated with explosives compounds above the risk-based remedial action objective of 25 μg/g for 2,4,6-TNT-related compounds and 10 μg/g for RDX-related compounds from surface soil and subsurface soil (to a maximum depth of 10 feet) through excavation. The excavated soil would then be treated and disposed in compliance with State and Federal laws and regulations. The optional engineered caps would provide long-term isolation of explosives-contaminated surface soil, and would prevent contaminant leaching to groundwater.

- Alternative C would involve the use of incineration, which would permanently destroy the explosives compounds to very low levels.

- Alternative D would involve the use of a bioremediation technique, which would biodegrade and biotransform the explosives compounds to levels which would be suitable for disposal in a solid waste landfill. This alternative would be less costly than the use of incineration; however, the biologically treated soil would be disposed in an on-site solid waste landfill to contain the biotransformed and non-biodegradable explosives compounds of unknown toxicity which would remain in the treated soil. The following is a brief summary of the biological treatment options:

    - Windrow composting is a proven and cost effective method of reducing the levels of explosives compounds and the associated toxicity of explosives-contaminated soil; however, due to the addition of amendments, the volume of material to be disposed increases by up to 60 percent.

    - Bioslurry treatment can reduce the levels of explosives compounds and the associated toxicity of explosives-contaminated soil, and the volume of treated soil to be disposed is less than the volume after windrow composting; however, treatment of explosives-contaminated soil has only been performed in bench- and pilot-scale studies.

TABLE 7-1

COMPARISON OF COSTS FOR SOIL REMEDIATION ALTERNATIVES

Alternative	Description	Costs in 1994 Dollars		
		Capital Cost	Annual O&M Cost	Present Worth (30 yr, 5%)
B	Limited Action	$27,000	$39,000	$626,000
C	Excavation/ Storage/ Incineration/ Backfill and Cover with Topsoil Optional Engineered Caps	$24,100,000	$40,000	$24,700,000
D	Excavation/ Storage/ Windrow Composting/ On-Site Landfill Optional Engineered Caps	$15,800,000	$44,000	$16,500,000
	Excavation/ Storage/ Bioslurry Treatment/ On-Site Landfill Optional Engineered Caps	$18,100,000	$44,000	$18,800,000

TABLE 7-2

ALTERNATIVES COMPARISON SUMMARY

Alternative	Protects Human Health and Environment?	Complies with ARARs?	Effective/ Permanent for Long-Term?	Reduces Toxicity, Mobility, or Volume through Treatment?	Effective Short-Term?	Implementable?	Accepted by Regulatory Agencies?	Accepted by Community?
A No Action	No	Yes	No	No	Yes	Not Applicable	Not Available	Not Available
B Limited Action	No	Yes	No	No	Yes	Yes	Not Available	Not Available
C Excavation/ Storage/ Incineration/ Backfill and Cover with Topsoil	Yes	Yes	Yes	Yes	Yes	Yes	Not Available	Not Available
D Excavation/ Storage/ Biological Treatment/ On-Site Landfill	Yes	Yes	Yes	Yes	Yes	Yes	Not Available	Not Available

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APPENDIX A

DERIVATION OF RISK-BASED REMEDIATION GOALS FOR SOIL FOR THE PROTECTION OF GROUNDWATER QUALITY

CONCENTRATION IN GROUNDWATER RESULTING FROM LEACHING FROM SOIL

DESIGNED BY NMO DATE 8/24

CHECKED BY [illegible] DATE 8-[illegible]

1. CALCULATE TOTAL MASS OF EXPLOSIVE COMPOUND IN SOIL AFTER EXCAVATING SOIL WITH EXPLOSIVES COMPOUNDS AT LEVELS ABOVE C_{MAX}

$$m_{TOT} = C_{AVE} \left(1 \times 10^{-6}\, g/\mu g\right) \rho_b\, A\, D\, (1-\phi) \qquad (1)$$

WHERE: C_{AVE} = DEPTH- AND AREA-AVERAGED CONCENTRATION OF EACH EXPLOSIVES COMPOUND ($\mu g/g$)

ρ_b = BULK DENSITY OF SOIL ($2.65\ g/cm^3$)

A = AREA OF LOAD LINE (cm^2)

D = THICKNESS OF VADOSE ZONE (cm)

ϕ = POROSITY (0.3)

m_{TOT} IN GRAMS

$$C_{AVE} = \frac{C_{MAX}}{2} f_{AREA} \frac{D_{EXP}}{D} \qquad (2)$$

WHERE C_{MAX} = MAXIMUM CONCENTRATION OF EXPLOSIVES COMPOUND AFTER EXCAVATION AND $\frac{C_{MAX}}{2}$ IS THE AVERAGE CONCENTRATION.

f_{AREA} = FRACTION OF LOAD LINE AREA THAT CONTAINS EXPLOSIVES COMPOUNDS AT CONCENTRATIONS BETWEEN MDL AND C_{MAX}

D_{EXP} = DEPTH WITHIN VADOSE ZONE THAT CONTAINS EXPLOSIVES COMPOUNDS AT CONCENTRATIONS BETWEEN MDL AND C_{MAX}

SUBSTITUTING EQN. (2) INTO (1)

$$m_{TOT} = \frac{C_{MAX}}{2} f_{AREA} \frac{D_{EXP}}{D} (1\times10^{-6}\, g/\mu g)\, \rho_b\, A D (1-\phi)$$

$$= \frac{C_{MAX}}{2} f_{AREA} \frac{D_{EXP}}{D} A\,(FT^2)\, D\,(FT) \times$$
$$2.83\times10^{4}\,(cm^3/FT^3)\,(1\times10^{-6}\, g/\mu g)\,\rho_b (1-\phi)$$

$$m_{TOT} = \frac{C_{MAX}}{2} f_{AREA}\, D_{EXP}\,(FT)\, A\,(FT^2) \left[5.3\times10^{-2}\right] g \qquad (3)$$

2. CALCULATE CONCENTRATION OF EXPLOSIVES COMPOUND IN GROUNDWATER RESULTING FROM LEACHING OF CONTAMINANT FROM SOIL.

ASSUMPTIONS :

a) TOTAL MASS OF EXPLOSIVES COMPOUND LEACHES AT A CONSTANT RATE FOR 30 YEARS (SIMILAR TO EPA'S VHS MODEL).

b) CONTAMINANT MIXES IN UPPER D_A FEET OF AQUIFER

c) NO IMPACTS FROM UPGRADIENT SOURCES ARE CONSIDERED

d) EXISTING GROUNDWATER CONTAMINATION IS NOT CONSIDERED. THIS IS THE INCREMENTAL CHANGE IN GROUNDWATER QUALITY.

CONCENTRATION IN GROUNDWATER RESULTING FROM LEACHING FROM SOIL

DESIGNED BY NMO DATE 8/24

CHECKED BY [illegible] DATE [illegible]

2a. TOTAL VOLUME OF GROUNDWATER IMPACTED BY LEACHING OF EXPLOSIVES COMPOUND FROM SOIL IS EQUAL TO THE VOLUME OF WATER UNDER THE LOAD LINE PLUS THE VOLUME THAT MOVES UNDER THE LOAD LINE IN A 30-YEAR PERIOD.

$$V_{TOT} = L\, D_A\, (vT + W)\, \phi\, (28.3\ L/FT^3) \quad (4)$$

WHERE:

L = LENGTH OF LOAD LINE PERPENDICULAR TO GROUNDWATER FLOW (FT)

D_A = MIXING ZONE IN AQUIFER (FT)

v = GROUNDWATER FLOW VELOCITY (72 FT/YR, FROM RI REPORT, 1991)

T = 30 YEARS

W = WIDTH OF LOAD LINE PARALLEL TO GROUNDWATER FLOW (FT)

ϕ = POROSITY OF AQUIFER MATERIAL (0.3)

26. CONCENTRATION OF EXPLOSIVES COMPOUND IN GROUNDWATER :

$$C_{GW} = \frac{m_{TOT}}{V_{TOT}} (1 \times 10^6) \qquad (\mu g/L)$$

SUBSTITUTE EQNS. (3) AND (4):

$$C_{GW} = \frac{\frac{C_{MAX}}{2} f_{AREA} D_{EXP}(FT)\, A(FT^2) \left[5.3 \times 10^{-2}\right] (1 \times 10^6)}{L\, D_A (vT + W)\, \phi\, (28.3\ L/FT^3)}$$

SUBSTITUTE : $A = L \cdot W$

$\phi = 0.3$

$$C_{GW} = \frac{\frac{C_{MAX}}{2} f_{AREA} D_{EXP}(FT)\, W(FT)}{D_A (vT + W)} \left[6.2 \times 10^3\right] \qquad (5)$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Estimate of Mixing Zone Depth

The mixing zone depth within the groundwater at the Northern Industrial Areas of MAAP was calculated for the explosives compounds which would leach to the groundwater. The equation used to calculate the mixing zone depth was taken from the Review Draft of the USEPA Technical Background Document for Soil Screening Guidance (EPA/540/R-94/106). The actual equation is based on an equation used in the MULTIMED groundwater model (Sharp-Hansen, et al, 1990). The derived equation is as follows:

$$d = (0.0112L^2)^{0.5} + d_a\left[1 - \exp\left(\frac{-LI}{Kid_a}\right)\right]$$

where: d = mixing zone depth (m)
- L = Source length parallel to groundwater flow (m)
- d_a = aquifer thickness (m)
- I = infiltration rate (m/yr)
- K = aquifer hydraulic conductivity (m/yr)
- i = hydraulic gradient (m/m)

I, K, and i were taken from a hydrogeological report prepared for MAAP (USAEC, 1994). The values from this report include:

$$I = 4.7 \text{ in/yr} \left(\frac{0.9144 \text{ m}}{36 \text{ in}}\right) = 0.1194 \text{ m/yr}$$

$$K = 57 \text{ ft/day} \left(\frac{1 \text{ m}}{3.281 \text{ ft}}\right)\left(\frac{365 \text{ days}}{\text{yr}}\right) = 6341 \text{ m/yr}$$

$$i = 0.0015 \text{ ft/ft} = 0.0015 \text{ m/m}$$

The source length parallel to groundwater flow was based on the average load line at MAAP

$$L = 1000 \text{ ft} \left(\frac{1 \text{ m}}{3.281 \text{ ft}}\right) = 305 \text{ m}$$

ICF KAISER ENGINEERS

Job No. 04302403?0

Focused FS for Northern Industrial Area Soil

Calculation of Mixing Zone Depth

DESIGNED BY R.R.L. DATE 2/10/

CHECKED BY [illegible] DATE 2/23/

Two mixing scenarios were examined:

1) Mixing would be confined by the confining clay layer at MAAP. Based on the hydrogeologic report (USAEC, 1994), the aquifer thickness would be approximately 220 ft.

$$d_a = 220\,ft\left(\frac{1m}{3.281ft}\right) = 67m$$

$$\therefore\ d = (0.0012(305)^2)^{0.5} + 67\left[1 - \exp\left(\frac{-(305)(.1194)}{(6341)(0.0015)(67)}\right)\right] = 14.29m$$

$$= (14.29m)\left(\frac{3.281\,ft}{1m}\right) = 46.89\,ft \sim \boxed{47\,ft}$$

2) Mixing could occur down to bedrock. The aquifer thickness to bedrock is approximately 2000 feet.

$$d_a = 2000\,ft\left(\frac{1m}{3.281ft}\right) = 610m$$

$$\therefore\ d = (0.0012(305)^2)^{0.5} + 610\left[1 - \exp\left(\frac{-(305)(.1194)}{(6341)(.0015)(610)}\right)\right] = 14.38m$$

$$= 14.38m\left(\frac{3.281\,ft}{1m}\right) = 47.18\,ft \sim \boxed{47\,ft}$$

Therefore, regardless of whether the confining clay layer is accounted for or not:

$$\boxed{\text{The mixing zone depth} = 47\,ft}$$

APPENDIX B

CALCULATION SHEETS FOR COST ESTIMATES

ICF KAISER ENGINEERS

Job No. 04302 40320

Alternative C: Incineration

Site Preparation

DESIGNED BY RRL DATE 9/1/

CHECKED BY [illegible] DATE

Site preparation of the incinerator site is required. Staging and preparation areas, stock pile areas for [illegible] [illegible] and treated soil, and a firm surface for placement of the mobile incineration system.

1) Incineration System Concrete Pad

1/2 acre concrete pad is required for supporting the mobile rotary kiln incinerator.

- 6" concrete pad = $6.19/ft²

(1/2 acre)(43560 ft²/acre)($6.19/ft²) = $134,818 ~ $135,000

2) Contaminated Soil Storage Building

3 sided steel building w/concrete floor, decomp [illegible], lighting, leachate collection sump, and has no columns

Unit Cost ~ $13 - $14/ft² (Butler Building Systems)

Size = 100' x 100' w/ 23' height to accommodate dump truck tipping height

Cost = (100ft)(100ft)($14/ft²) = $140,000

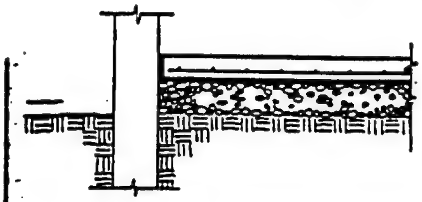
3) Roadway

A roadway will be constructed to allow access to the incinerator site

Approx. Size = 200' x 24' - 9" gravel, 3 1/2" pavement

Unit Cost = $68.50/ft

Cost = (200ft)($68.50/ft) = $13,700 ~ $14,000



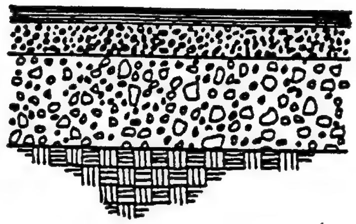
There are four types of Slab on Grade Systems listed: Non-industrial, Light industrial, Industrial and Heavy industrial. Each type is listed two ways: reinforced and non-reinforced. A Slab on Grade system includes three passes with a grader; 6" of compacted gravel fill; polyethylene vapor barrier; 3500 p.s.i. concrete placed by chute; bituminous fibre expansion joint; all necessary edge forms (4 uses); steel trowel finish; and sprayed-on membrane curing compound.

The Expanded System Listing shows costs on a per square foot basis. Thicknesses of the slabs range from 4" to 8". Non-industrial applications are for foot traffic only with negligible abrasion. Light industrial applications are for pneumatic wheels and light abrasion. Industrial applications are for solid rubber wheels and moderate abrasion. Heavy industrial applications are for steel wheels and severe abrasion. All slabs are either shown unreinforced or reinforced with welded wire fabric.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM 2.1-200-2220					
SLAB ON GRADE, 4" THICK, NON INDUSTRIAL, NON REINFORCED					
Fine grade, 3 passes with grader and roller	.110	S.Y.		.15	.15
Gravel under floor slab, 6" deep, compacted	1.000	S.F.	.17	.20	.37
Polyethylene vapor barrier, standard, .006" thick	1.000	S.F.	.04	.08	.12
Concrete ready mix, regular weight, 3500 psi	.012	C.Y.	.65		.65
Place and vibrate concrete for slab on grade, 4" thick, direct chute	.012	C.Y.		.17	.17
Expansion joint, premolded bituminous fiber, 1/2" x 6"	.100	L.F.	.12	.18	.30
Edge forms in place for slab on grade to 6" high, 4 uses	.030	L.F.	.01	.06	.07
Cure with sprayed membrane curing compound	1.000	S.F.	.02	.05	.07
Finishing floor, monolithic steel trowel	1.000	S.F.		.59	.59
TOTAL			1.01	1.48	2.49

2.1-200	Slab on Grade	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
2220	Slab on grade, 4" thick, non industrial, non reinforced	1.01	1.48	2.49
2240	Reinforced	1.09	1.70	2.79
2260	Light industrial, non reinforced	1.22	1.86	3.08
2300	Industrial, non reinforced	1.53	3.03	4.56
2320	Reinforced	1.61	3.25	4.86
3340	5" thick, non industrial, non reinforced	1.18	1.53	2.71
3360	Reinforced	1.26	1.75	3.01
3380	Light industrial, non reinforced	1.39	1.91	3.30
3400	Reinforced	1.47	2.13	3.60
3420	Heavy industrial, non reinforced	1.94	3.57	5.51
3440	Reinforced	2	3.81	5.81
4460	6" thick, non industrial, non reinforced	1.40	1.49	2.89
4480	Reinforced	1.52	1.78	3.30
4500	Light industrial, non reinforced	1.61	1.87	3.48
4520	Reinforced	1.80	2.27	4.07
4540	Heavy industrial, non reinforced	2.16	3.62	5.78
4560	Reinforced	2.28	3.91	6.19

B-2



The Bituminous Roadway Systems are listed for pavement thicknesses between 3-1/2" and 7" and gravel bases from 3" to 22" in depth. Systems costs are expressed per linear foot for varying widths of two and multi-lane roads. Earth moving is not included. Granite curbs and line painting are added as required system components.

System Components	QUANTITY	UNIT	COST PER L.F. MAT.	INST.	TOTAL
SYSTEM 12.5-111-1050					
BITUM. ROADWAY, TWO LANES, 3-1/2" TH. PVMT., 3" TH. GRAVEL BASE, 24' WIDE					
Compact subgrade, 4 passes	2.670	S.Y.		1.92	1.92
Bank gravel, 2 mi haul, dozer spread	.250	C.Y.	1.03	1.12	2.15
Compaction granular material to 98%	.250	C.Y.		.11	.11
Grading, fine grade, 3 passes with grader	2.670	S.Y.		4.55	4.55
Bituminous paving, binder course, 2-1/2" thick	2.670	S.Y.	9.72	2.43	12.15
Bituminous paving, wearing course, 1" thick	2.670	S.Y.	4.22	1.31	5.53
Curbs, granite, split face, straight, 5" x 16"	2.000	L.F.	28.20	9.84	38.04
Painting lines, reflectorized, 4" wide	1.000	L.F.	.31	.13	.44
TOTAL			43.48	21.41	64.89

12.5-111	Bituminous Roadways	COST PER L.F. MAT.	INST.	TOTAL
1050	Bitum. roadway, two lanes, 3-1/2" th. pvmt., 3" th. gravel base, 24' wide	43.50	21.50	65
1100	28' wide	46.50	22.50	69
1150	32' wide	48.50	24	72.50
1300	9" th. gravel base, 24' wide	45.50	23	68.50
1350	28' wide	48.50	25.50	74
1400	32' wide	51.50	27.50	79
1550	4" th. pvmt., 4" th. gravel base, 24' wide	45.50	21	66.50
1600	28' wide	48.50	23	71.50
1650	32' wide	51.50	25	76.50
1800	10" th. gravel base, 24' wide	48	23.50	71.50
1850	28' wide	51	26	77
1900	32' wide	54	28	82
2050	4" th. pvmt., 5" th. gravel base, 24' wide	46.50	22	68.50
2100	28' wide	49.50	24	73.50
2150	32' wide	52.50	26	78.50
2300	12" th. gravel base, 24' wide	49	25	74
2350	28' wide	52.50	27.50	80
2400	32' wide	55.50	30	85.50
2550	4-1/2" th. pvmt., 5" th. gravel base, 24' wide	48.50	22	70.50
2600	28' wide	51.50	24	75.50
2650	32' wide	55	26	81
2800	13" th. gravel base, 24' wide	51	25.50	76.50
2850	28' wide	55	28	83
2900	32' wide	58.50	30.50	89
3050	5" th. pvmt., 6" th. gravel base, 24' wide	50.50	23	73.50
3100	28' wide	54	25	79
3150	32' wide	58	27	85
3300	14" th. gravel base, 24' wide	53.50	26	79.50
3350	28' wide	57.50	29	86.50
3400	32' wide	61.50	31.50	93
3550	5-1/2" th. pvmt., 7" th. gravel base, 24' wide	53	23.50	76.50
3600	28' wide	57	26	83

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-3

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 2 of 4

Alternative C: Incineration

Site Preparation

DESIGNED BY RBL DATE 9/11

CHECKED BY [illegible] DATE 9/1[illegible]

4) Site Clearing

Clearing of the surrounding vegetation, leveling, and compacting to prepare for incineration equipment storage and staging and roadway

Area ~ 2 acres

Unit Cost = Reduce cost by 40% because trees will not be chipped, they will be burned at OBG

= (\$2,700/ac + \$1,200/acre)(60%) = \$2,340/ac

Hauling to OBG

Hauling to OBG will be a 5 mile round trip with a $12\ yd^3$ dump truck.

Assume $0.5\ ft^3$ of material per ft^2 of area cleared

Unit Cost = $(\$6.95/yd^3)(1yd^3/27ft^3)(0.5\ ft^3/ft^2)(\frac{43560\ ft^2}{acre})$ = \$5606/ac

Total Cost = (2 acre)(\$2,340/acre + \$5,606/acre) = \$15,892

~ \$16,000

$\boxed{\text{Total Cost} = \$16,000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

021 | Site Preparation and Excavation Support

021 100 | Site Clearing

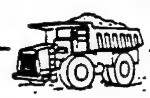
				DAILY	MAN-		1994 BARE COSTS				TOTAL
			CREW	OUTPUT	HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	INCL O&P
104	0010	CLEAR AND GRUB Light, trees to 6" diam., cut & chip	B-7	1	48	Acre		970	1,075	2,045	2,700
	0150	Grub stumps and remove	B-30	2	12			255	740	995	1,200
	0160	Clear & grub brush & stumps	"	.58	41.379			880	2,550	3,430	4,150
	0200	Medium, trees to 12" diam., cut & chip	B-7	.70	68.571			1,375	1,525	2,900	3,850
	0250	Grub stumps and remove	B-30	1	24			510	1,475	1,985	2,400
	0260	Clear & grub dense brush & stumps	"	.47	51.064			1,075	3,150	4,225	5,125
	0300	Heavy, trees to 24" diam., cut & chip	B-7	.30	160			3,225	3,575	6,800	9,025
	0350	Grub stumps and remove	B-30	.50	48			1,025	2,950	3,975	4,825
	0400	If burning is allowed, reduce cut & chip									40%
	3000	Chipping stumps, to 18" deep, 12" diam.	B-86	20	.400	Ea.		9.75	7.95	17.70	23.50
	3040	18" diameter		16	.500			12.20	9.95	22.15	29.50
	3080	24" diameter		14	.571			13.90	11.35	25.25	34
	3100	30" diameter		12	.667			16.25	13.25	29.50	39.50
	3120	36" diameter		10	.800			19.50	15.90	35.40	47.50
	3160	48" diameter		8	1			24.50	19.85	44.35	59.50
	5000	Tree thinning, feller buncher, conifer									
	5080	Up to 8" diameter	B-93	240	.033	Ea.		.81	1.42	2.23	2.80
	5120	12" diameter		160	.050			1.22	2.13	3.35	4.21
	5240	Hardwood, up to 4" diameter		240	.033			.81	1.42	2.23	2.80
	5280	8" diameter		180	.044			1.08	1.89	2.97	3.74
	5320	12" diameter		120	.067			1.62	2.84	4.46	5.60
	7000	Tree removal, congested area, aerial lift truck									
	7040	8" diameter	B-85	7	5.714	Ea.		115	110	225	300
	7080	12" diameter		6	6.667			135	128	263	350
	7120	18" diameter		5	8			162	154	316	425
	7160	24" diameter		4	10			202	193	395	525
	7240	36" diameter		3	13.333			269	257	526	705
	7280	48" diameter		2	20			405	385	790	1,050
108	0010	CLEARING Brush with brush saw	A-1	.25	32	Acre		610	234	844	1,225
	0100	By hand	"	.12	66.667			1,275	485	1,760	2,525
	0300	With dozer, ball and chain, light clearing	B-11A	2	8			173	410	583	720
	0400	Medium clearing	"	1.50	10.667			231	545	776	960
	0500	With dozer and brush rake, light	B-11B	1	16			345	1,025	1,370	1,675
	0550	Medium brush to 4" diameter		.60	26.667			580	1,725	2,305	2,775
	0600	Heavy brush to 4" diameter		.40	40			865	2,575	3,440	4,175
	1000	Brush mowing, tractor w/rotary mower, no removal									
	1020	Light density	B-84	2	4	Acre		97.50	104	201.50	264
	1040	Medium density		1.50	5.333			130	139	269	350
	1080	Heavy density		1	8			195	209	404	530
116	0010	FELLING TREES & PILING With tractor, large tract, firm									
	0020	level terrain, no boulders, less than 12" diam. trees									
	0300	300 HP dozer, up to 400 trees/acre, 0 to 25% hardwoods	B-10M	.75	16	Acre		360	1,325	1,685	2,000
	0340	25% to 50% hardwoods		.60	20			450	1,650	2,100	2,525
	0370	75% to 100% hardwoods		.45	26.667			600	2,225	2,825	3,350
	0400	500 trees/acre, 0% to 25% hardwoods		.60	20			450	1,650	2,100	2,525
	0440	25% to 50% hardwoods		.48	25			565	2,075	2,640	3,150
	0470	75% to 100% hardwoods		.36	33.333			750	2,775	3,525	4,225
	0500	More than 600 trees/acre, 0 to 25% hardwoods		.52	23.077			520	1,925	2,445	2,900
	0540	25% to 50% hardwoods		.42	28.571			645	2,375	3,020	3,600
	0570	75% to 100% hardwoods		.31	38.710			875	3,200	4,075	4,875
	0900	Large tract clearing per tree									
	1500	300 HP dozer, to 12" diameter, softwood	B-10M	320	.038	Ea.		.85	3.11	3.96	4.73
	1550	Hardwood		100	.120			2.71	9.95	12.66	15.15
	1600	12" to 24" diameter, softwood		200	.060			1.35	4.98	6.33	7.60
	1650	Hardwood		80	.150			3.39	12.45	15.84	18.95

SITE WORK 2

B-5

022 200 | Excav./Backfill/Compact.

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
262	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
266	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



B-6

Alternative C: Incineration

Site Preparation

DESIGNED BY RBL DATE 9/1
CHECKED BY DATE

5) Treated Soil Storage

Storage for 1½ week buffer of soil to be backfilled

Soil density = 125 lbs/ft² w/ 1.2 Bulking factor

Weight: (5 tons/hr)(168 hrs/week)(1.5 weeks) = 1,260 tons

Volume = (1,260 tons)(2000 lbs/ton)(ft³/125 lb)(1.2) = 24,192 ft³

Area = (24,192 ft³)(1/8 ft pile)(1 acre/43560 ft²) = 0.07 acre ~0.1 acre

Assume 0.1 acres for Staging & Prep area

Total area ≃ 0.25 acres

Pavement Unit Cost - 3" Binder Course = $5.30/yd²
2" Wearing Course = $4.07/yd²
$9.37/yd²

Cost = (1/4 acre)(43560 ft²/acre)(1 yd²/9 ft²)($9.37/yd²) = $11,337
~$12,000

Curbing

8" machine formed curb around perimeter

Length = $\left(\sqrt{(1/4\,\text{acre})(43560\,\text{ft}^2/\text{ac})}\right)4 = 420'$

Unit cost = $2.24/ft

Cost = ($2.24/ft)(420 ft) = $941 ~$1000

$\boxed{\text{Total Cost} \sim \$13{,}000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

024 | Railroad and Marine Work

024 820 | Dredging

	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
824	1600	For inland rivers and canals in South, deduct				C.Y.				30%	30%	824

024 840 | Seawall & Bulkheads

	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
844	0010	BULKHEADS Reinforced concrete, include footing and tie-backs										844
	0060	Maximum	C-17C	24.25	3.423	L.F.	41	86	16	143	206	
	0100	12' high, minimum		20	4.150		78	104	19.40	201.40	281	
	0160	Maximum		18.50	4.486		85	112	21	218	305	
	0200	Steel sheeting, w/4' x 4' x 8" concrete deadmen, @ 10' O.C.										
	0210	12' high, shore driven	B-40	27	2.370	L.F.	50	57.50	69	176.50	230	
	0260	Barge driven	B-76	15	4.800	•	50	116	125	291	395	

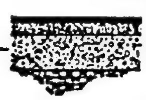
024 880 | Docks & Facilities

	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
882	0010	DOCKS Floating, recreational, prefabricated aluminum or										882
	0020	concrete over polystyrene, no pilings included	F-3	330	.121	S.F.	23	2.92	1.29	27.21	32	
	0200	Pile supported, shore constructed, bare, 3" decking		130	.308		13.65	7.40	3.26	24.31	31	
	0250	4" decking		120	.333		14.75	8.05	3.54	26.34	33.50	
	0400	Floating, small boat, prefab, no shore facilities, minimum		250	.160		6.50	3.86	1.70	12.06	15.45	
	0500	Maximum		150	.267		22	6.45	2.83	31.28	38	
	0700	Per slip, minimum (180 S.F. each)		1.59	25.157	Ea.	1,200	605	267	2,072	2,625	
	0800	Maximum		1.40	28.571	•	4,500	690	305	5,495	6,425	

025 | Paving and Surfacing

025 100 | Walk/Rd/Parkng Paving

	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
104	0010	ASPHALTIC CONCRETE PAVEMENT for highways (R025-110)										104
	0020	and large paved areas										
	0080	Binder course, 1-1/2" thick (R025-120)	B-25	7,725	.011	S.Y.	1.99	.24	.21	2.44	2.81	
	0120	2" thick		6,345	.014		2.65	.29	.25	3.19	3.67	
	0160	3" thick (R025-130)		4,905	.018		3.94	.37	.33	4.64	5.30	
	0200	4" thick		4,140	.021		5.25	.44	.39	6.08	6.95	
	0300	Wearing course, 1" thick	B-25B	10,575	.009		1.44	.19	.17	1.80	2.08	
	0340	1-1/2" thick		7,725	.012		2.18	.26	.24	2.68	3.09	
	0380	2" thick		6,345	.015		2.93	.32	.29	3.54	4.07	
	0420	2-1/2" thick		5,480	.018		3.62	.37	.33	4.32	4.96	
	0460	3" thick		4,900	.020		4.31	.41	.37	5.09	5.85	
	0800	Alternate method of figuring paving costs										
	0810	Binder course, 1-1/2" thick	B-25	630	.140	Ton	26	2.88	2.56	31.44	36	
	0811	2" thick		690	.128		26	2.63	2.34	30.97	35.50	
	0812	3" thick		800	.110		26	2.27	2.02	30.29	34.50	
	0813	4" thick		900	.098		26	2.02	1.79	29.81	34	
	0850	Wearing course, 1" thick	B-25B	575	.167		26.50	3.50	3.19	33.19	39	
	0851	1-1/2" thick		630	.152		26.50	3.19	2.91	32.60	38	
	0852	2" thick		690	.139		26.50	2.91	2.66	32.07	37	
	0853	2-1/2" thick		745	.129		26.50	2.70	2.46	31.66	36.50	
	0854	3" thick		800	.120		26.50	2.51	2.29	31.30	36	
	1000	Pavement replacement over trench, 2" thick	B-37	90	.533	S.Y.	1.47	10.70	1.50	13.67	21	
	1050	4" thick		70	.686		6.45	13.75	1.93	22.13	32	
	1080	6" thick		55	.873		9.95	17.50	2.46	29.91	42.50	



13-8

2 SITE WORK

025 150 | Unit Pavers

Ref.	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	Ref.
166	1110	1-1/2" thick	D-1	90	.178	S.F.	1.95	3.91		5.86	8.65	166
	1120	Pavers, 1/2" thick		110	.145		2.75	3.20		5.95	8.30	
	1130	3/4" thick		95	.168		3.50	3.71		7.21	10	
	1140	1" thick		81	.198		3.75	4.35		8.10	11.30	
	1150	Snapped random rectangular, 1" thick		92	.174		2.50	3.83		6.33	9.10	
	1200	1-1/2" thick		85	.188		3	4.14		7.14	10.20	
	1250	2" thick		83	.193		3.50	4.24		7.74	10.90	
	1300	Slate, natural cleft, irregular, 3/4" thick		92	.174		1.50	3.83		5.33	8	
	1310	1" thick		85	.188		1.75	4.14		5.89	8.80	
	1350	Random rectangular, gauged, 1/2" thick		105	.152		3.25	3.36		6.61	9.10	
	1400	Random rectangular, butt joint, gauged, 1/4" thick		150	.107		3.50	2.35		5.85	7.75	
	1450	For sand rubbed finish, add					2.30			2.30	2.53	
	1500	For interior setting, add								25%	25%	
	1550	Granite blocks, 3-1/2" x 3-1/2" x 3-1/2"	D-1	92	.174	S.F.	4.61	3.83		8.44	11.40	
	1560	4" x 4" x 4"		95	.168		4.86	3.71		8.57	11.50	
	1600	4" to 12" long, 3" to 5" wide, 3" to 5" thick		98	.163		3.84	3.60		7.44	10.20	
	1650	6" to 15" long, 3" to 6" wide, 3" to 5" thick		105	.152		2.05	3.36		5.41	7.80	

025 250 | Curbs

Ref.	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	Ref.
254	0010	CURBS Asphaltic, machine formed, 8" wide, 6" high, 40 L.F./ton	B-27	1,000	.032	L.F.	.65	.62	.06	1.33	1.83	254
	0100	8" wide, 8" high, 30 L.F. per ton		900	.036		.90	.69	.07	1.66	2.24	
	0150	Asphaltic berm, 12"W, 3"-6"H, 35 L.F./ton, before pavement		700	.046		.75	.89	.09	1.73	2.42	
	0200	12"W, 1-1/2"to 4" H, 60 L.F. per ton, laid with pavement	B-2	1,050	.038		.45	.74		1.19	1.74	
	0300	Concrete, 6" x 18", wood forms, straight	C-2	500	.096		3.10	2.24	.07	5.41	7.25	
	0400	6" x 18", radius	"	200	.240		3.26	5.60	.18	9.04	13.25	
	0421	Curb and gutter, straight										
	0422	with 6" high curb and 6" thick gutter, wood forms										
	0430	24" wide, .055 C.Y. per L.F.	C-2	375	.128	L.F.	4.65	2.99	.10	7.74	10.25	
	0435	30" wide, .066 C.Y. per L.F.	"	340	.141		5.60	3.29	.11	9	11.80	
	0550	Precast, 6" x 18", straight	B-29	700	.080		5.25	1.64	.86	7.75	9.45	
	0600	6" x 18", radius		325	.172		7.95	3.52	1.86	13.33	16.65	
	1000	Granite, split face, straight, 5" x 16"		500	.112		12.80	2.29	1.21	16.30	19.25	
	1300	Radius curbing, 6" x 18", over 10' radius		260	.215		20.50	4.40	2.32	27.22	32.50	
	1400	Corners, 2' radius		80	.700	Ea.	69	14.30	7.55	90.85	108	
	1600	Edging, 4-1/2" x 12", straight		300	.187	L.F.	6.40	3.82	2.01	12.23	15.60	
	1800	Curb inlets, (guttermouth) straight		41	1.366	Ea.	154	28	14.75	196.75	232	
258	0010	EDGING										258
	0050	Edging aluminum alloy,including stakes, 1/8" x 4", mill finish	B-1	390	.062	L.F.	1.60	1.21		2.81	3.80	
	0051	Edging, aluminum alloy,1/8" x 4", Black paint		390	.062		1.86	1.21		3.07	4.08	
	0052	Edging, aluminum alloy 1/8" x 4", Black anodized		390	.062		2.14	1.21		3.35	4.40	
	0060	Edging, aluminum alloy, 3/16" x 4", mill finish		380	.063		2.30	1.24		3.54	4.62	
	0061	Edging, aluminum alloy, 3/16" x 4", Black paint		380	.063		2.66	1.24		3.90	5	
	0062	Edging, aluminum alloy, 3/16" x 4", Black anodized		380	.063		3.10	1.24		4.34	5.50	
	0070	Edging, aluminum alloy. 1/8" x 5 1/2" mill finish		370	.065		2.32	1.28		3.60	4.70	
	0071	Edging, aluminum alloy, 1/8" x 5-1/2", Black paint		370	.065		2.75	1.28		4.03	5.20	
	0072	Edging, aluminum alloy, 1/8" x 5-1/2", Black anodized		370	.065		3.15	1.28		4.43	5.60	
	0080	Edging, aluminum alloy, 3/16" x 5 1/2" mill finish		360	.067		3.10	1.31		4.41	5.60	
	0081	Edging, aluminum alloy, 3/16" x 5-1/2", Black paint		360	.067		3.50	1.31		4.81	6.05	
	0082	Edging, aluminum alloy, 3/16" x 5-1/2", Black anodized		360	.067		4.05	1.31		5.36	6.65	
	0100	Brick, set horizontally, 1-1/2 per L.F.	D-1	370	.043		.80	.95		1.75	2.46	
	0150	Brick, set vertically, 3 per L.F.	"	135	.119		1.60	2.61		4.21	6.10	
	0200	Edging, corrugated aluminum,4" wide	F-1	650	.012		.16	.29	.01	.46	.69	
	0250	Edging, corrugated aluminum. 6" wide	"	550	.015		.20	.35	.02	.57	.82	
	0300	Concrete, cast in place, see 025-254										

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-9

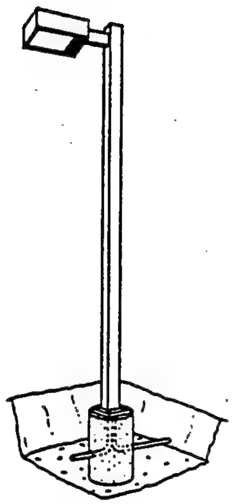
6) Site Lighting 400 watt Mercury Vapor lamp
-Assume 1000 ft² illumination area
20' Aluminum light Pole
18" dia x 9" high base
Unit Cost = $1991.75/light

Number = (2 acres)(43560 ft²/acre)(1-light/1000 ft²) = 87 lights

Cost = (87 lights)($1991.75/light) = $173,282
~$174,000

Lighting O&M Cost for 87-400 watt lamps

Cost = ($0.10/kwhr)(400 watt/lamp)(1 kw/1000 watt)(87 lamps)(12 hr/day)(365 days/yr)
= $15,242 ~ $\boxed{\$16,000}$



The Site Lighting System includes the complete unit from foundation to electrical fixtures. Each system includes: excavation; concrete base; backfill by hand; compaction with a plate compacter; pole of specified material; all fixtures; and lamps.

The Expanded System Listing shows Site Lighting Systems that use one of three types of lamps: high pressure sodium; mercury vapor; and metal halide. Systems are listed for 400-watt and 1000-watt lamps. Pole height varies from 20' to 40'. There are four types of poles listed: aluminum, fiberglass, steel and wood.

System Components	QUANTITY	UNIT	COST EACH MAT.	INST.	TOTAL
SYSTEM 12.7-500-3620					
SITE LIGHTING,MERCURY VAPOR, 400 WATT, ALUMINUM POLE, 20' HIGH					
Excavating, by hand, pits to 6' deep, heavy soil	.237	C.Y.		142.08	142.08
Concrete in place incl.forms and reinf.stl.spread footings under 1CY	.047	C.Y.	37.90	51.20	89.10
Backfill, including compaction	1.903	C.Y.		48.32	48.32
Aluminum light pole, 20', no concrete base	1.000	Ea.	600	323.50	923.50
Roadway area luminaire, mercury vapor	1.000	Ea.	626.30	162.45	788.75
TOTAL			1,264.20	727.55	1,991.75

12.7-500	Site Lighting	COST EACH MAT.	INST.	TOTAL
2320	Site lighting, high pressure sodium, 400 watt, aluminum pole, 20' high	1,450	730	2,180
2340	30' high	2,050	895	2,945
2360	40' high	2,700	1,175	3,875
2520	Fiberglass pole, 20' high	1,450	635	2,085
2540	30' high	2,125	790	2,915
2560	40' high	2,600	1,025	3,625
2720	Steel pole, 20' high	1,700	760	2,460
2740	30' high	2,025	945	2,970
2760	40' high	2,325	1,250	3,575
2920	Wood pole, 20' high	1,125	705	1,830
2940	30' high	1,275	895	2,170
2960	40' high	1,525	1,100	2,625
3120	1000 watt, aluminum pole, 20' high	1,575	745	2,320
3140	30' high	2,175	910	3,085
3160	40' high	2,825	1,175	4,000
3320	Fiberglass pole, 20' high	1,575	650	2,225
3340	30' high	2,250	805	3,055
3360	40' high	2,725	1,025	3,750
3420	Steel pole, 20' high	1,825	775	2,600
3440	30' high	2,150	960	3,110
3460	40' high	2,450	1,250	3,700
3520	Wood pole, 20' high	1,275	720	1,995
3540	30' high	1,400	910	2,310
3560	40' high	1,650	1,100	2,750

B-11

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 1 of 2

Alternative C: Incineration

Contaminated Soil Removal

DESIGNED BY RRL DATE 9/1/9

CHECKED BY DATE

1) Clear top 2" of Soil and Stackpile

Area = $(18,500\,yd^3)(27\,ft^3/yd^3)(1/10\,ft\ excavation) = 49,950\,ft^2$

Volume = $(49,950\,ft^2)(2")(\frac{1\,ft}{12"})(\frac{yd^3}{27\,ft^3}) = 308\,yd^3$

Unit Cost = $1.14/$yd^3$

Cost = $308\,yd^3$ ($1.14/$yd^3$) = $351 ~ $400

Note: Must analyze topsoil to determine if it is non-hazardous

2) Confirmatory Sampling

Approximately 5000 Samples for topsoil and subsurface Confirmatory Sampling with test kits

Unit Cost = $50/sample

Cost = (5000 samples)($50/sample) = $250,000

3) Contaminated Soil Excavation

Excavation of contaminated soil will be performed with a 1½ yd^3 backhoe - add 15% for loading onto trucks

Unit Cost = $1.65/$yd^3$ (1.15) = $1.90/$yd^3$

Cost = $(18,500\,yd^3)$($1.90/$yd^3$) = $35,150

~ $36,000

CALCULATIONS KE Form No. E-6 Rev. 12-89

021 100 | Site Clearing

	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
116	1700	24" to 36" diameter, softwood	B-10M	100	.120	Ea.		2.71	9.95	12.66	15.15	116
	1750	Hardwood		50	.240			5.40	19.90	25.30	30.50	
	1800	36" to 48" diameter, softwood		70	.171			3.87	14.20	18.07	21.50	
	1850	Hardwood		35	.343			7.75	28.50	36.25	43.50	

021 140 | Stripping

	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	
144	0010	STRIPPING Topsoil, and stockpiling, sandy loam										144
	0020	200 H.P. dozer, ideal conditions	B-10B	2,300	.005	C.Y.		.12	.36	.48	.57	
	0100	Adverse conditions	•	1,150	.010			.24	.71	.95	1.14	
	0200	300 HP dozer, ideal conditions	B-10M	3,000	.004			.09	.33	.42	.51	
	0300	Adverse conditions	•	1,650	.007			.16	.60	.76	.91	
	0400	400 HP dozer, ideal conditions	B-10X	3,900	.003			.07	.32	.39	.46	
	0500	Adverse conditions	•	2,000	.006			.14	.63	.77	.90	
	0600	Clay, dry and soft, 200 HP dozer, ideal conditions	B-10B	1,600	.008			.17	.51	.68	.82	
	0601	Strip topsoil, clay, dry & soft, 200 HP dozer, ideal conditions		1,600	.008			.17	.51	.68	.82	
	0700	Adverse conditions		800	.015			.34	1.02	1.36	1.65	
	1000	Medium hard, 300 HP dozer, ideal conditions	B-10M	2,000	.006			.14	.50	.64	.76	
	1100	Adverse conditions	•	1,100	.011			.25	.91	1.16	1.38	
	1200	Very hard, 400 HP dozer, ideal conditions	B-10X	2,600	.005			.10	.48	.58	.69	
	1300	Adverse conditions	•	1,340	.009			.20	.94	1.14	1.34	

021 150 | Selective Clearing

	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	
154	0010	SELECTIVE CLEARING										154
	1000	Stump removal on site by hydraulic backhoe, 1-1/2 C.Y.										
	1050	8" to 12" diameter	B-30	33	.727	Ea.		15.45	45	60.45	73.50	
	1100	14" to 24" diameter		25	.960			20.50	59	79.50	96.50	
	1150	26" to 36" diameter		16	1.500			32	92.50	124.50	151	
	1151	Stump removal, 19" to 24" diameter		16	1.500			32	92.50	124.50	151	
	2000	Remove selective trees, on site using chain saws and chipper,										
	2050	not incl. stumps, up to 6" diameter	B-7	18	2.667	Ea.		54	59.50	113.50	151	
	2100	8" to 12" diameter		12	4			81	89.50	170.50	225	
	2150	14" to 24" diameter		10	4.800			97	107	204	271	
	2200	26" to 36" diameter		8	6			121	134	255	340	
	2300	Machine load, 2 mile haul to dump, 12" diam. tree, add								40	60	

021 200 | Structure Moving

	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	
204	0010	MOVING BUILDINGS One day move, up to 24' wide										204
	0020	Reset on new foundation, patch & hook-up, average move				Total					8,500	
	0040	Wood or steel frame bldg., based on ground floor area	B-4	185	.259	S.F.		5.05	2.35	7.40	10.55	
	0060	Masonry bldg., based on ground floor area	•	137	.350			6.80	3.17	9.97	14.25	
	0200	For 24' to 42' wide, add									15%	
	0220	For each additional day on road, add	B-4	1	48	Day		935	435	1,370	1,950	
	0240	Construct new basement, move building, 1 day										
	0300	move, patch & hook-up, based on ground floor area	B-3	155	.310	S.F.	5.30	6.35	10.20	21.85	27	

021 400 | Dewatering

	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	
404	0010	DEWATERING Excavate drainage trench, 2' wide, 2' deep	B-11C	90	.178	C.Y.		3.85	2.22	6.07	8.45	404
	0100	2' wide, 3' deep, with backhoe loader	•	135	.119			2.57	1.48	4.05	5.65	
	0200	Excavate sump pits by hand, light soil	1 Clab	7.10	1.127			21.50		21.50	34	
	0300	Heavy soil	•	3.50	2.286			43.50		43.50	69	
	0500	Pumping 8 hr., attended 2 hrs. per day, including 20 L.F.										
	0550	of suction hose & 100 L.F. discharge hose										
	0600	2" diaphragm pump used for 8 hours	B-10H	4	3	Day		67.50	7.80	75.30	114	
	0620	Add per additional pump							30	26	33	
	0650	4" diaphragm pump used for 8 hours	B-10I	4	3			67.50	19.90	87.40	127	
	0670	Add per additional pump							63	68	69	

13-13

022 200 | Excav./Backfill/Compact.

			Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
234	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04	234
	4600	Maximum	•	15,100	.002	•		.04		.04	.07	
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25	
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25	
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14	
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73	
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27	
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4	
	5460	4 mile round trip		200	.040			.79	2.98	3.77	4.49	
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer										
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88	
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20	
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05	
	5820	300' haul		200	.060			1.35	4.98	6.33	7.60	
238	0010	EXCAVATING, BULK BANK MEASURE Common earth piled R022-240										238
	0020	For loading onto trucks, add								15%	15%	
	0050	For mobilization and demobilization, see division 022-274 R022-250										
	0100	For hauling, see division 022-266										
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.62	.88	1.50	1.91	
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65	
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53	
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77	
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82	
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89	
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr.	B-12G	160	.100			2.31	2.82	5.13	6.65	
	0550	1 C.Y. cap. = 35 C.Y./hr.	B-12H	280	.057			1.32	1.91	3.23	4.12	
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50	
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1001	3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69	
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71	
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44	
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23	
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23	
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1	
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84	
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20	
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12	
	1601	3 C.Y. cap. = 100 C.Y./hr.	•	1,100	.011			.25	.40	.65	.82	
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96	
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15	
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11	
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44	
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69	
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28	
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18	
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87	
	4000	For soft soil or sand, deduct								15%	15%	
	4100	For heavy soil or stiff clay, add								60%	60%	
	4200	For wet excavation with clamshell or dragline, add								100%	100%	
	4250	All other equipment, add								50%	50%	
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20	
	4450	Maximum	•	60	.267			6.15	8.90	15.05	19.25	
	8000	For hauling excavated material, see div. 022-266										
242	0010	EXCAVATING, BULK, DOZER Open site										242
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56	

SITE WORK 2

B-14

4) Contaminated Soil Hauling

Soil will be hauled with a 12yd³ dump trucks
- assume a 5 mile round trip

Unit Cost = $6.95/yd³

Cost = (18,500 yd³)(1.2 Bulking factor)($6.95/yd³) = $154,290
~$155,000

5) Confirmation Sampling

10% of the TNT and RDX immunoassay samples will be sent to a lab for confirmatory HPLC analysis. Samples will be collected at the bottom of each excavation. Add 15% to the number of samples collected to account for duplicates and blanks.

Unit Cost = $350/sample; includes analysis and sample QA/QC

Samples = (5000 Immunoassays)(0.10)(1.15) = 575 samples

Cost = (575 samples)($350/sample) = $201,250 ~ $202,000

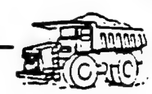
Source: ESE Laboratories, Gainsville, FL

Total Cost = $400 + $250,000 + $36,000 + $155,000 + $202,000 = $643,000
~$643,000

$\boxed{\text{Total Cost} = \$643{,}000}$

022 200 | Excav./Backfill/Compact.

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
262	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
266	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	[illegible]
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	[illegible]
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-16

ICF KAISER ENGINEERS

Job No. 04302403 00
Sheet 1 of 1

Alternative C8 Incineration
Treated Soil Disposal

DESIGNED BY RRL DATE 9/1/
CHECKED BY DATE 9/1/

1) Treated Soil from Storage to Backfill Area

Loading of the treated soil into 12 yd³ dump trucks will be performed with a 1½ yd³ front end loader. Trucks will have a 4 mile round trip.

Unit Costs: Front End Loader = $1.20/yd³
12 yd³ dump Truck = $4.54/yd³
$5.74/yd³

Cost = (22,200 yd³)($5.74/yd³) = $127,428
≈ $128,000

2) Backfill and Compact Treated Soil

Backfilling of the soil into the borrow area performed with a 50' haul, 8" lifts with 2 passes of the compactor

Unit Cost = $2.37/yd³

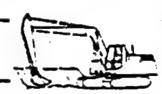
Cost = (22,200 yd³)($2.37/yd³) = $52,614
≈ $53,000

Total Cost = $128,000 + $53,000 = $181,000

$\boxed{\text{Total Cost} = \$181,000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

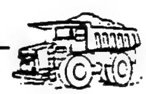
022 200 | Excav./Backfill/Compact.

	Line	Description	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
4	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04	234
	4600	Maximum	"	15,100	.002	"		.04		.04	.07	
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25	
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25	
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14	
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73	
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27	
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4	
	5460	4 mile round trip	↓	200	.040	↓		.79	2.98	3.77	4.49	
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer										
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88	
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20	
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05	
	5820	300' haul	↓	200	.060	↓		1.35	4.98	6.33	7.60	
238	0010	**EXCAVATING, BULK BANK MEASURE** Common earth piled R022-240										238
	0020	For loading onto trucks, add								15%	15%	
	0050	For mobilization and demobilization, see division 022-274 R022-250										
	0100	For hauling, see division 022-266										
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.52	.98	1.50	1.91	
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65	
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53	
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77	
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82	
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89	
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr.	B-12G	160	.100			2.31	2.82	5.13	6.65	
	0550	1 C.Y. cap. = 35 C.Y./hr. 	B-12H	280	.057			1.32	1.91	3.23	4.12	
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50	
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1001	3/4 C.Y. cap. = 35 C.Y./hr.	↓	280	.057			1.32	1.67	2.99	3.86	
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69	
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71	
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44	
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23	
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23	
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1	
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84	
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20	
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12	
	1601	3 C.Y. cap. = 100 C.Y./hr.	"	1,100	.011			.25	.40	.65	.82	
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96	
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15	
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11	
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44	
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69	
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28	
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18	
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87	
	4000	For soft soil or sand, deduct								15%	15%	
	4100	For heavy soil or stiff clay, add								60%	60%	
	4200	For wet excavation with clamshell or dragline, add								100%	100%	
	4250	All other equipment, add								50%	50%	
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20	
	4450	Maximum	"	60	.267	↓		6.15	8.90	15.05	19.25	
	8000	For hauling excavated material, see div. 022-266										
242	0010	**EXCAVATING, BULK, DOZER** Open site										242
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56	

SITE WORK 2

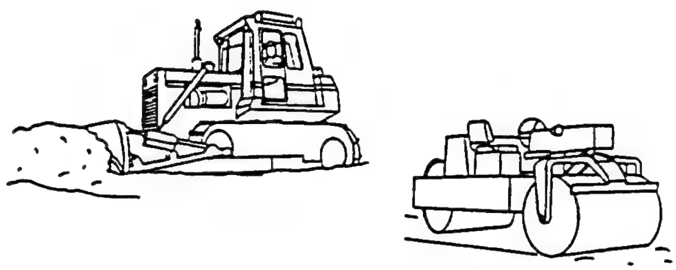
1-set
1-att

13-18

		022 200 | Excav./Backfill/Compact.	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
252	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
266	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.52	5.37	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr. 		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55

13-19

Common Earth Backfill



The Common Earth Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Common Earth Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-724-1000					
EARTH BACKFILL, 75 HP DOZER & ROLLER, 50' HAUL, 4" LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, common earth, from stockpile	1.000	C.Y.	.31	.43	.74
Water wagon, rent per day	.004	Hr.	.27	.12	.39
Compaction, roller, 4" lifts, 2 passes	.035	Hr.	.65	1.84	2.49
Total			1.23	2.39	3.62

12.1-724	Common Earth Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Earth backfill,75 HP dozer & roller compactors,50' haul,4" lifts,2 passes	1.23	2.39	3.62
1050	4 passes	1.88	4.23	6.11
1100	8" lifts, 2 passes	.91	1.50	2.41
1150	4 passes	1.23	2.39	3.62
1200	150' haul, 4" lifts, 2 passes	1.53	2.82	4.35
1250	4 passes	2.18	4.66	6.84
1300	8" lifts, 2 passes	1.21	1.93	3.14
1350	4 passes	1.53	2.82	4.35
1400	300' haul, 4" lifts, 2 passes	1.83	3.23	5.06
1450	4 passes	2.48	5.05	7.53
1500	8" lifts, 2 passes	1.51	2.34	3.85
1550	4 passes	1.83	3.23	5.06
1600	105 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.28	2.30	3.58
1650	4 passes	1.93	4.14	6.07
1700	8" lifts, 2 passes	.96	1.41	2.37
1750	4 passes	1.28	2.30	3.58
1800	150' haul, 4" lifts, 2 passes	1.65	2.65	4.30
1850	4 passes	2.30	4.49	6.79
1900	8" lifts, 2 passes	1.33	1.76	3.09
1950	4 passes	1.65	2.65	4.30
2000	300' haul, 4" lifts, 2 passes	1.99	2.97	4.96
2050	4 passes	2.64	4.81	7.45
2100	8" lifts, 2 passes	1.67	2.08	3.75
2150	4 passes	1.99	2.97	4.96
2200	200 HP dozer & roller compactors, 150' haul, 4" lifts, 2 passes	1.70	1.55	3.25
2250	4 passes	2.31	2.60	4.91
2300	8" lifts, 2 passes	1.40	1.03	2.43
2350	4 passes	1.70	1.55	3.25
2600	300' haul, 4" lifts, 2 passes	2.11	1.74	3.85
2650	4 passes	2.72	2.79	5.51
2700	8" lifts, 2 passes	1.81	1.22	3.03
2750	4 passes	2.11	1.74	3.85

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-20

ICF KAISER ENGINEERS

JOB No. 04302403.00

SHEET 1 OF 1

Alternative C: Incinerator

Clean Soil Cover

DESIGNED BY RRG DATE 9/1/

CHECKED BY [illegible] DATE [illegible]

Clean Soil Cover will be an 8-inch thick layer of soil covering an area of 1.5 acres

$$\text{Volume} = (1.5\ \text{acres})\left(\frac{43{,}560\ ft^2}{acre}\right)\left(\frac{8}{12}\ \text{feet}\right) = 43{,}560\ ft^3$$

Unit Costs Excavate & Haul = \$7.08/yd³ (12.1-414-3200)

Backfill \$0.74 / yd³ (121-724-2750)

\$7.82/yd³

$$\text{Cost} = (\$7.82/yd^3)(43{,}560\ ft^3)\left(\frac{1\ yd^3}{27\ ft^3}\right) = \$12{,}616$$

$\approx \$13{,}000$

Revegetate

Revegetation will include hydroseeding with mulch and fertilizer

Unit Cost = \$39/1000 ft²

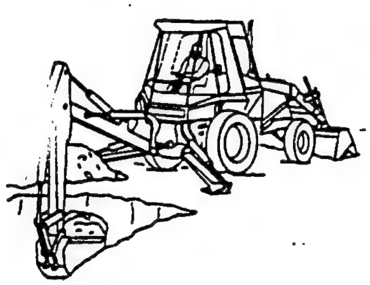
$$\text{Cost} = (1.4\ \text{acres})\left(\frac{43560\ ft^2}{acre}\right)(\$39/1000\ ft^2) = \$2{,}378$$

$\approx \$3{,}000$

$$\text{Total Cost} = \$13{,}000 + \$3{,}000 = \boxed{\$16{,}000}$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Excavate Common Earth



The Excavation of Common Earth System balances the productivity of the excavating equipment to the hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 25% for hauling.

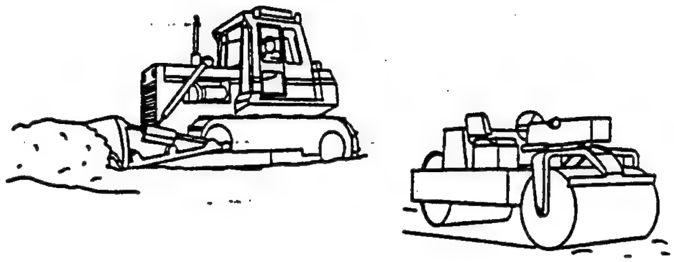
The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 3-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Dragline bucket rigs range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-414-1000					
EXCAVATE COMMON EARTH, 1/2 $FF3 CY BACKHOE, TWO 6 CY DUMP TRUCKS, 1 MRT					
Excavating, bulk hyd. backhoe wheel mtd., 1/2 C.Y.	1.000	C.Y.	.92	1.49	2.41
Haul earth, 6 C.Y. dump truck, 1 mile round trip, 3.3 loads/hr	1.000	C.Y.	1.86	1.26	3.12
Spotter at earth fill dump or in cut	.020	Hr.		.48	.48
Total			2.78	3.23	6.01

12.1-414	Excavate Common Earth	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Excavate common earth, 1/2 C.Y. backhoe,two 6 C.Y. dump trucks, 1MRT	2.78	3.23	6.01
1200	Three 6 C.Y. dump trucks, 3 mile round trip	5.45	5.10	10.55
1400	Two 12 C.Y. dump trucks, 4 mile round trip	4.60	4.05	8.65
1600	3/4 C.Y. backhoe, three C.Y. dump trucks, 1 mile round trip	2.69	2.58	5.27
1700	Five 6 C.Y. dump trucks, 3 mile round trip	5.25	4.58	9.83
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.55	2.93	6.48
1900	Two 16 C.Y. dump trailers, 3 mile round trip	3.61	2.41	6.02
2000	Two 20 C.Y. dump trailers, 4 mile round trip	3.67	2.54	6.21
2200	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.15	3.92	9.07
2300	Four 12 C.Y. dump trucks, 2 mile round trip	3.27	2.31	5.58
2400	Six 12 C.Y. dump trucks, 4 mile round trip	4.26	2.82	7.08
2500	Three 16 C.Y. dump trailers, 2 mile round trip	3.14	1.79	4.93
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.41	1.47	3.88
2700	Three 20 C.Y. dump trailer, 3 mile round trip	3.22	1.83	5.05
2800	2-1/2 C.Y. backhoe, six 12 C.Y. dump trucks, 1 mile round trip	2.59	1.60	4.19
2900	Eight 12 C.Y. dump trucks, 3 mile round trip	3.56	2.18	5.74
3000	Four 16 C.Y. dump trailers, 1 mile round trip	2.54	1.30	3.84
3100	Six 16 C.Y. dump trailers, 3 mile round trip	3.41	1.78	5.19
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.36	1.75	5.11
3400	3-1/2 C.Y. backhoe, six 16 C.Y. dump trailers, 1 mile round trip	3.03	1.29	4.32
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.25	1.85	6.10
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.51	1.52	5.03
4000	1/2 C.Y. pwr. shovel, four 6 C.Y. dump trucks, 2 mile round trip	4.27	3.50	7.77
4100	Two 12 C.Y. dump trucks, 1 mile round trip	2.77	2.21	4.98
4200	Four 12 C.Y. dump trucks, 4 mile round trip	4.21	2.90	7.11
4300	Two 16 C.Y. dump trailers, 2 mile round trip	3.09	2.07	5.16
4400	Two 20 C.Y. dump trailers, 4 mile round trip	3.57	2.41	5.98
4500				
4800	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.15	3.37	7.52
4900	Three 12 C.Y. dump trucks, 1 mile round trip	2.66	1.88	4.54
5000	Five 12 C.Y. dump trucks, 4 mile round trip	4.21	2.78	6.99
5100	Three 16 C.Y. dump trailers, 3 mile round trip	3.49	2.08	5.57
5200	Three 20 C.Y. dump trailers, 4 mile round trip	3.44	2.05	5.49
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 1 mile round trip	2.54	1.59	4.13

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-22



The Common Earth Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Common Earth Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
SYSTEM 12.1-724-1000					
EARTH BACKFILL, 75 HP DOZER & ROLLER , 50' HAUL, 4"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, common earth, from stockpile	1.000	C.Y.	.31	.43	.74
Water wagon, rent per day	.004	Hr.	.27	.12	.39
Compaction, roller, 4" lifts, 2 passes	.035	Hr.	.65	1.84	2.49
Total			1.23	2.39	3.62

12.1-724	Common Earth Backfill	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
1000	Earth backfill,75 HP dozer & roller compactors,50' haul,4" lifts,2 passes	1.23	2.39	3.62
1050	4 passes	1.88	4.23	6.11
1100	8" lifts, 2 passes	.91	1.50	2.41
1150	4 passes	1.23	2.39	3.62
1200	150' haul, 4" lifts, 2 passes	1.53	2.82	4.35
1250	4 passes	2.18	4.66	6.84
1300	8" lifts, 2 passes	1.21	1.93	3.14
1350	4 passes	1.53	2.82	4.35
1400	300' haul, 4" lifts, 2 passes	1.83	3.23	5.06
1450	4 passes	2.48	5.05	7.53
1500	8" lifts, 2 passes	1.51	2.34	3.85
1550	4 passes	1.83	3.23	5.06
1600	105 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.28	2.30	3.58
1650	4 passes	1.93	4.14	6.07
1700	8" lifts, 2 passes	.96	1.41	2.37
1750	4 passes	1.28	2.30	3.58
1800	150' haul, 4" lifts, 2 passes	1.65	2.65	4.30
1850	4 passes	2.30	4.49	6.79
1900	8" lifts, 2 passes	1.33	1.76	3.09
1950	4 passes	1.65	2.65	4.30
2000	300' haul, 4" lifts, 2 passes	1.99	2.97	4.96
2050	4 passes	2.64	4.81	7.45
2100	8" lifts, 2 passes	1.67	2.08	3.75
2150	4 passes	1.99	2.97	4.96
2200	200 HP dozer & roller compactors, 150' haul, 4" lifts, 2 passes	1.70	1.55	3.25
2250	4 passes	2.31	2.60	4.91
2300	8" lifts, 2 passes	1.40	1.03	2.43
2350	4 passes	1.70	1.55	3.25
2600	300' haul, 4" lifts, 2 passes	2.11	1.74	3.85
2650	4 passes	2.72	2.79	5.51
2700	8" lifts, 2 passes	1.81	1.22	3.03
2750	4 passes	2.11	1.74	3.85

SITE WORK 12

See the Reference Section for reference number information, Crew Listings and City Cost Indexe

B-23

029 | Landscaping

029 200 | Soil Preparation

		029 200 Soil Preparation	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
204	6000	Tilling topsoil, 20 HP tractor, disk harrow, 2" deep	B-66	50,000	.001	S.Y.					.01	204
	6050	4" deep		40,000	.001						.02	
	6100	6" deep		30,000	.001			.01	.01	.02	.02	
	6150	26" rototiller, 2" deep	A-1	1,250	.006			.12	.05	.17	.25	
	6200	4" deep		1,000	.008			.15	.06	.21	.32	
	6250	6" deep		750	.011			.20	.08	.28	.43	
	7000	Lawn maintenance see Division 029-700										
208	0010	PLANT BED PREPARATION										208
	0100	Backfill planting pit, by hand, on site topsoil	2 Clab	18	.889	C.Y.		16.90		16.90	28.50	
	0200	Prepared planting mix	"	24	.667			12.65		12.65	21.50	
	0300	Skid steer loader, on site topsoil	B-62	340	.071			1.44	.28	1.72	2.70	
	0400	Prepared planting mix	"	410	.059			1.20	.23	1.43	2.24	
	1000	Excavate planting pit, by hand, sandy soil	2 Clab	16	1			19		19	32	
	1100	Heavy soil or clay	"	8	2			38		38	64	
	1200	1/2 C.Y. backhoe, sandy soil	B-11C	150	.107			2.31	1.33	3.64	5.25	
	1300	Heavy soil or clay	"	115	.139			3.02	1.74	4.76	6.85	
	2000	Mix planting soil, incl. loam, manure, peat, by hand	2 Clab	60	.267		24	5.05		29.05	35	
	2100	Skid steer loader	B-62	150	.160		24	3.28	.64	27.92	32.50	
	3000	Pile sod, skid steer loader	"	2,800	.009	S.Y.		.18	.03	.21	.33	
	3100	By hand	2 Clab	400	.040			.76		.76	1.28	
	4000	Remove sod, F.E. loader	B-10S	2,000	.006			.14	.16	.30	.39	
	4100	Sod cutter	B-12K	3,200	.005			.12	.26	.38	.48	
	4200	By hand	2 Clab	240	.067			1.27		1.27	2.13	

029 300 | Lawns & Grasses

		029 300 Lawns & Grasses	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
308	0010	SEEDING Athletic field mix, 8#/M.S.F., push spreader R029-310	A-1	10	.800	M.S.F.	11.80	15.20	5.85	32.85	45	308
	0100	Tractor spreader	B-66	52	.154		11.80	3.60	3.51	18.91	22.50	
	0200	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	0400	Birdsfoot trefoil, .45#/M.S.F., push spreader	A-1	10	.800		13.95	15.20	5.85	35	47.50	
	0500	Tractor spreader	B-66	52	.154		13.95	3.60	3.51	21.06	25	
	0600	Hydro or air seeding,with mulch & fertil.	B-81	80	.300		28.50	6.30	6.90	41.70	49.50	
	0800	Bluegrass, 4#/M.S.F., common, push spreader	A-1	10	.800		5.05	15.20	5.85	26.10	37.50	
	0900	Tractor spreader	B-66	52	.154		5.05	3.60	3.51	12.16	15.20	
	1000	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		19.15	6.30	6.90	32.35	39	
	1100	Baron, push spreader	A-1	10	.800		10.60	15.20	5.85	31.65	43.50	
	1200	Tractor spreader	B-66	52	.154		10.60	3.60	3.51	17.71	21.50	
	1300	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	1500	Clover, 0.67#/M.S.F., white, push spreader	A-1	10	.800		2.50	15.20	5.85	23.55	34.50	
	1600	Tractor spreader	B-66	52	.154		2.50	3.60	3.51	9.61	12.40	
	1700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		16.65	6.30	6.90	29.85	36.50	
	1800	Ladino, push spreader	A-1	10	.800		4.23	15.20	5.85	25.28	36.50	
	1900	Tractor spreader	B-66	52	.154		4.23	3.60	3.51	11.34	14.30	
	2000	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		18.20	6.30	6.90	31.40	38	
	2200	Fescue 5.5#/M.S.F., tall, push spreader	A-1	10	.800		7.35	15.20	5.85	28.40	40	
	2300	Tractor spreader	B-66	52	.154		7.35	3.60	3.51	14.46	17.70	
	2400	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		22.50	6.30	6.90	35.70	42.50	
	2500	Chewing, push spreader	A-1	10	.800		8.55	15.20	5.85	29.60	41.50	
	2600	Tractor spreader	B-66	52	.154		8.55	3.60	3.51	15.66	19.05	
	2700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		23.50	6.30	6.90	36.70	43.50	
	2900	Crown vetch, 4#/M.S.F., push spreader	A-1	10	.800		38.50	15.20	5.85	59.55	74.50	
	3000	Tractor spreader	B-66	52	.154		38.50	3.60	3.51	45.61	52	
	3100	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		53	6.30	6.90	66.20	76	
	3300	Rye, 10#/M.S.F., annual, push spreader	A-1	10	.800		4.83	15.20	5.85	25.88	37	
	3400	Tractor spreader	B-66	52	.154		4.83	3.60	3.51	11.94	14.95	
	3500	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		18.25	6.30	6.90	31.45	38	

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-24

ICF KAISER ENGINEERS

Job No. 0430240300

Sheet 1 of 1

Alternative C: Incineration

Optional Engineered Caps

DESIGNED BY RBL DATE 9/1/9

CHECKED BY DATE 9/1

The engineered caps will consist of a 3" layer of binder course asphalt over a 6" layer of gravel. Clearing and grubbing of the contaminated areas would be performed prior to cap placement. The area to be covered with engineered caps is assumed to be approximately 20,000 ft² for cost comparison

1) Clearing and Grubbing

Clear area for optional engineered caps. Reduce cost by 40% because trees will be burned at OBG, not chipped

$Area = (20{,}000\ ft^2)(\frac{1\ acre}{43560\ ft^2}) = 0.46\ acres$

$Unit\ Cost = (\$2700/ac + \$1200/ac)(60\%) = \$2340/ac$

Hauling to OBG

Hauling will be a 5 mile round trip with a 12 yd³ dump truck. Assume 0.5 ft³ of material for every ft² cleared

$Unit\ Cost = (\$6.95/yd^3)(\frac{1\ yd^3}{27\ ft^3})(\frac{0.5\ ft^3}{ft^2})(\frac{43560\ ft^2}{acre}) = \$5606/ac$

$Total\ Cost = (0.46\ acres)(\$2340/ac + \$5606/ac) = 3655$
$\sim \$4{,}000$

2) 6" Gravel Layer

$Volume = (6/12)(20{,}000\ ft^2)(1\ yd^3/27\ ft^3) = 370\ yd^3$

Unit Cost = Load and Haul = \$6.30/yd³
Backfill and Compact = \$2.02/yd³
8.32/yd³

$Cost = (370\ yd^3)(\$8.32/yd^3) = \$3{,}078 \sim \$3{,}000$

3) 3" Asphalt Layer

$Area = (20{,}000\ ft^2)(\frac{1\ yd^2}{9\ ft^2}) = 2{,}222\ yd^2$

$Unit\ Cost = \$5.25/yd^2$

$Cost = (2{,}222\ yd^2)(5.25/yd^2) = \$11{,}666 \sim \$12{,}000$

$Total\ Cost = \$4{,}000 + \$3000 + \$12{,}000 = \boxed{\$19{,}000}$

021 100 | Site Clearing

		021 100 Site Clearing	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
104	0010	CLEAR AND GRUB Light, trees to 6" diam., cut & chip	B-7	1	48	Acre		970	1,075	2,045	2,700	104
	0150	Grub stumps and remove	B-30	2	12	↓		255	740	995	1,200	
	0160	Clear & grub brush & stumps	"	.58	41.379	↓		880	2,550	3,430	4,150	
	0200	Medium, trees to 12" diam., cut & chip	B-7	.70	68.571	↓		1,375	1,525	2,900	3,850	
	0250	Grub stumps and remove	B-30	1	24	↓		510	1,475	1,985	2,400	
	0260	Clear & grub dense brush & stumps	"	.47	51.064	↓		1,075	3,150	4,225	5,125	
	0300	Heavy, trees to 24" diam., cut & chip	B-7	.30	160	↓		3,225	3,575	6,800	9,025	
	0350	Grub stumps and remove	B-30	.50	48	↓		1,025	2,950	3,975	4,825	
	0400	If burning is allowed, reduce cut & chip				↓					40%	
	3000	Chipping stumps, to 18" deep, 12" diam.	B-86	20	.400	Ea.		9.75	7.95	17.70	23.50	
	3040	18" diameter	↓	16	.500	↓		12.20	9.95	22.15	29.50	
	3080	24" diameter	↓	14	.571	↓		13.90	11.35	25.25	34	
	3100	30" diameter	↓	12	.667	↓		16.25	13.25	29.50	39.50	
	3120	36" diameter	↓	10	.800	↓		19.50	15.90	35.40	47.50	
	3160	48" diameter	↓	8	1	↓		24.50	19.85	44.35	59.50	
	5000	Tree thinning, feller buncher, conifer										
	5080	Up to 8" diameter	B-93	240	.033	Ea.		.81	1.42	2.23	2.80	
	5120	12" diameter	↓	160	.050	↓		1.22	2.13	3.35	4.21	
	5240	Hardwood, up to 4" diameter	↓	240	.033	↓		.81	1.42	2.23	2.80	
	5280	8" diameter	↓	180	.044	↓		1.08	1.89	2.97	3.74	
	5320	12" diameter	↓	120	.067	↓		1.62	2.84	4.46	5.60	
	7000	Tree removal, congested area, aerial lift truck										
	7040	8" diameter	B-85	7	5.714	Ea.		115	110	225	300	
	7080	12" diameter	↓	6	6.667	↓		135	128	263	350	
	7120	18" diameter	↓	5	8	↓		162	154	316	425	
	7160	24" diameter	↓	4	10	↓		202	193	395	525	
	7240	36" diameter	↓	3	13.333	↓		269	257	526	705	
	7280	48" diameter	↓	2	20	↓		405	385	790	1,050	
108	0010	CLEARING Brush with brush saw	A-1	.25	32	Acre		610	234	844	1,225	108
	0100	By hand	"	.12	66.667	↓		1,275	485	1,760	2,525	
	0300	With dozer, ball and chain, light clearing	B-11A	2	8	↓		173	410	583	720	
	0400	Medium clearing	"	1.50	10.667	↓		231	545	776	960	
	0500	With dozer and brush rake, light	B-11B	1	16	↓		345	1,025	1,370	1,675	
	0550	Medium brush to 4" diameter	↓	.60	26.667	↓		580	1,725	2,305	2,775	
	0600	Heavy brush to 4" diameter	↓	.40	40	↓		865	2,575	3,440	4,175	
	1000	Brush mowing, tractor w/rotary mower, no removal										
	1020	Light density	B-84	2	4	Acre		97.50	104	201.50	264	
	1040	Medium density	↓	1.50	5.333	↓		130	139	269	350	
	1080	Heavy density	↓	1	8	↓		195	209	404	530	
116	0010	FELLING TREES & PILING With tractor, large tract, firm										116
	0020	level terrain, no boulders, less than 12" diam. trees										
	0300	300 HP dozer, up to 400 trees/acre, 0 to 25% hardwoods	B-10M	.75	16	Acre		360	1,325	1,685	2,000	
	0340	25% to 50% hardwoods	↓	.60	20	↓		450	1,650	2,100	2,525	
	0370	75% to 100% hardwoods	↓	.45	26.667	↓		600	2,225	2,825	3,350	
	0400	500 trees/acre, 0% to 25% hardwoods	↓	.60	20	↓		450	1,650	2,100	2,525	
	0440	25% to 50% hardwoods	↓	.48	25	↓		565	2,075	2,640	3,150	
	0470	75% to 100% hardwoods	↓	.36	33.333	↓		750	2,775	3,525	4,225	
	0500	More than 600 trees/acre, 0 to 25% hardwoods	↓	.52	23.077	↓		520	1,925	2,445	2,900	
	0540	25% to 50% hardwoods	↓	.42	28.571	↓		645	2,375	3,020	3,600	
	0570	75% to 100% hardwoods	↓	.31	38.710	↓		875	3,200	4,075	4,875	
	0900	Large tract clearing per tree										
	1500	300 HP dozer, to 12" diameter, softwood	B-10M	320	.038	Ea.		.85	3.11	3.96	4.73	
	1550	Hardwood	↓	100	.120	↓		2.71	9.95	12.66	15.15	
	1600	12" to 24" diameter, softwood	↓	200	.060	↓		1.35	4.98	6.33	7.60	
	1650	Hardwood	↓	80	.150	↓		3.39	12.45	15.84	18.95	

B-26

Load & Haul Sand & Gravel

The Loading and Hauling of Sand and Gravel System balances the productivity of loading equipment to hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route.

The Expanded System Listing shows Loading and Hauling systems that use either a track or wheel front-end loader. Track loaders indicated range from 1-1/2 Cubic Yards capacity to 4-1/2 Cubic Yards capacity. Wheel loaders range from 1-1/2 Cubic Yards to 5 Cubic Yards. Trucks for hauling range from 12 Cubic Yards capacity to 20 Cubic Yards capacity. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-612-1000					
LOAD & HAUL SAND & GRAVEL,1-1/2$FF3 CY LOADER, FOUR 12 CY TRUCKS, 1MRT					
Excavating bulk, F.E. loader, track mtd., 1/2 C.Y.	1.000	C.Y.	.43	.47	.90
Haul earth, 12 C.Y. dump truck, 1 mile round trip, 2.7 loads/hr	1.000	C.Y.	1.94	1.07	3.01
Spotter at earth fill dump or in cut	.040	Hr.		.12	.12
Total			2.37	1.66	4.03

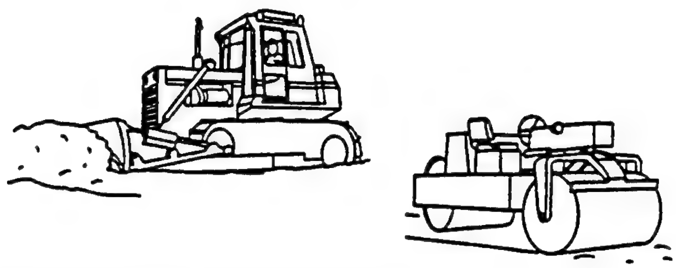
12.1-612 Load & Haul Sand & Gravel

12.1-612	Load & Haul Sand & Gravel	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Load & haul sand&gravel,1-1/2CY tr.loader,four 12CY dump trucks,1MRT	2.37	1.66	4.03
1200	Six 12 C.Y. dump trucks, 3 mile round trip	3.22	2.23	5.45
1400	Four 16 C.Y. dump trailers, 3 mile round trip	3.13	1.84	4.97
1600	Three 20 C.Y. dump trailers, 2 mile round trip	2.42	1.52	3.94
1800	Four 20 C.Y.dump trailers, 4 mile round trip	3.07	1.81	4.88
2000	2-1/2 C.Y. track loader, six 12 C.Y. dump trucks, 2 mile round trip	2.87	1.92	4.79
2200	Eight 12 C.Y. dump trucks, 4 mile round trip	3.84	2.46	6.30
2400	Five 16 C.Y. dump trailers, 3 mile round trip	3.16	1.71	4.87
2600	Three 20 C.Y. dump trailers, 1 mile round trip	2.06	1.22	3.28
3000	3-1/2 C.Y. track loader, six 12 C.Y. dump trucks, 1 mile round trip	2.58	1.56	4.14
3200	Six 16 C.Y. dump trailers, 2 mile round trip	2.87	1.48	4.35
3600	Eight 16 C.Y. dump trailers, 4 mile round trip	3.57	1.76	5.33
4000	4-1/2 C.Y. track loader, six 16 C.Y. dump trailers, 1 mile round trip	2.37	1.13	3.50
4200	Eight 16 C.Y. dump trailers, 2 mile round trip	2.76	1.30	4.06
4400	Eight 20 C.Y. dump trailers, 3 mile round trip	2.82	1.34	4.16
4600	Nine 20 C.Y. dump trailers, 4 mile round trip	3.11	1.46	4.57
5000	1-1/2 C.Y. wheel loader, four 12 C.Y. dump trucks, 1 mile round trip	2.33	1.65	3.98
5200	Six 12 C.Y. dump trucks, 3 mile round trip	3.18	2.23	5.41
5400	Four 16 C.Y. dump trailers, 2 mile round trip	2.64	1.56	4.20
5600	Five 16 C.Y. dump trailers, 4 mile round trip	3.36	1.90	5.26
6000	3 C.Y. wheel loader, ten 12 C.Y.dump trucks, 3 mile round trip	3.03	1.89	4.92
6200	Five 16 C.Y. dump trailers, 1 mile round trip	2.08	1.11	3.19
6400	Six 16 C.Y. dump trailers, 2 mile round trip	2.51	1.40	3.91
6600	Seven 20 C.Y. dump trailers, 4 mile round trip	2.85	1.52	4.37
7000	5 C.Y. wheel loader, eight 16 C.Y. dump trailers, 1 mile round trip	2.26	1.08	3.34
7200	Twelve 16 C.Y. dump trailers, 3 mile round trip	3.06	1.44	4.50
7400	Nine 20 C.Y. dump trailers, 2 mile round trip	2.36	1.13	3.49
7600	Twelve 20 C.Y. dump trailers, 4 mile round	3.01	1.42	4.43

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-27

Gravel Backfill



The Gravel Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Gravel Backfilling operations with bulldozers ranging from 75 H.P. to 300 H.P. The maximum hauling distance ranges from 50' to 300'. Lifts for the compaction range from 6" to 12". There is no waste included in the assumptions.

System Components

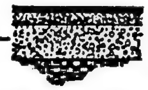
System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-722-1000					
GRAVEL BACKFILL, 75 HP DOZER & COMPACTORS,50' HAUL, 6" LIFTS,2 PASSES					
Backfilling, dozer, 75 H.P., 50' haul, sand and gravel, from stockpile	1.000	C.Y.	.27	.38	.65
Water wagon rent per day	.003	Hr.	.20	.09	.29
Compaction, vibrating roller, 6" lifts, 2 passes	1.000	C.Y.	.23	.86	1.09
Total			.70	1.33	2.03

12.1-722 Gravel Backfill

12.1-722	Gravel Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Gravel backfill, 75 HP dozer & compactors, 50' haul, 6"lifts, 2 passes	.70	1.33	2.03
1050	4 passes	1.07	2.25	3.32
1100	12" lifts, 2 passes	.45	.84	1.29
1150	4 passes	.70	1.33	2.03
1200	150' haul, 6" lifts, 2 passes	.97	1.71	2.68
1250	4 passes	1.34	2.63	3.97
1300	12" lifts, 2 passes	.84	1.65	2.49
1350	4 passes	.97	1.71	2.68
1400	300' haul, 6" lifts, 2 passes	1.24	2.08	3.32
1450	4 passes	1.61	3	4.61
1500	12" lifts, 2 passes	.99	1.59	2.58
1550	4 passes	1.24	2.08	3.32
1600	105 HP dozer & vibrating compactors, 50' haul, 6" lifts, 2 passes	.76	1.26	2.02
1650	4 passes	1.13	2.18	3.31
1700	12" lifts, 2 passes	.51	.77	1.28
1750	4 passes	.76	1.26	2.02
1800	150' haul, 6" lifts, 2 passes	1.09	1.58	2.67
1850	4 passes	1.46	2.50	3.96
1900	12" lifts, 2 passes	.84	1.09	1.93
1950	4 passes	1.09	1.58	2.67
2000	300' haul, 6" lifts, 2 passes	1.38	1.85	3.23
2050	4 passes	1.75	2.77	4.52
2100	12" lifts, 2 passes	1.13	1.36	2.49
2150	4 passes	1.38	1.85	3.23
2200	200 HP dozer & roller compactors, 150' haul, 6" lifts, 2 passes	1.08	.59	1.67
2250	4 passes	1.35	.81	2.16
2300	12" lifts, 2 passes	.88	.45	1.33
2350	4 passes	1.08	.59	1.67
2600	300' haul, 6" lifts, 2 passes	1.46	.77	2.23
2650	4 passes	1.73	.99	2.72
2700	12" lifts, 2 passes	1.26	.63	1.89
2750	4 passes	1.46	.77	2.23

B-28

025 100 | Walk/Rd/Parkng Paving

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
104	0080	Binder course, 1-1/2" thick	B-25	7,725	.011	S.Y.	1.99	.24	.21	2.44	2.79
	0120	2" thick		6,345	.014		2.65	.29	.25	3.19	3.65
	0160	3" thick		4,905	.018		3.94	.37	.33	4.64	5.25
	0200	4" thick 		4,140	.021		5.25	.44	.39	6.08	6.90
	0300	Wearing course, 1" thick	B-25B	10,575	.009		1.44	.19	.17	1.80	2.07
	0340	1-1/2" thick		7,725	.012		2.18	.26	.24	2.68	3.07
	0380	2" thick		6,345	.015		2.93	.32	.29	3.54	4.05
	0420	2-1/2" thick		5,480	.018		3.62	.37	.33	4.32	4.92
	0460	3" thick		4,900	.020		4.31	.41	.37	5.09	5.80
	0800	Alternate method of figuring paving costs									
	0810	Binder course, 1-1/2" thick	B-25	630	.140	Ton	26	2.88	2.56	31.44	36
	0811	2" thick		690	.128		26	2.63	2.34	30.97	35
	0812	3" thick		800	.110		26	2.27	2.02	30.29	34.50
	0813	4" thick		900	.098		26	2.02	1.79	29.81	33.50
	0850	Wearing course, 1" thick	B-25B	575	.167		26.50	3.50	3.19	33.19	38.50
	0851	1-1/2" thick		630	.152		26.50	3.19	2.91	32.60	37.50
	0852	2" thick		690	.139		26.50	2.91	2.66	32.07	37
	0853	2-1/2" thick		745	.129		26.50	2.70	2.46	31.66	36.50
	0854	3" thick		800	.120		26.50	2.51	2.29	31.30	36
	1000	Pavement replacement over trench, 2" thick	B-37	90	.533	S.Y.	1.47	10.70	1.50	13.67	20
	1050	4" thick		70	.686		6.45	13.75	1.93	22.13	30.50
	1080	6" thick		55	.873		9.95	17.50	2.46	29.91	41
108	0010	ASPHALTIC CONCRETE At the plant (145 lb. per C.F.) R025-110				Ton	23.50			23.50	26
	0200	All weather patching mix					26.50			26.50	29
	0300	Berm mix					26.50			26.50	29
	0400	Base mix					23.50			23.50	26
	0500	Binder mix					23.50			23.50	26
	0600	Sand or sheet mix					27.50			27.50	30
	2000	Reclaimed pavement in stockpile					9.55			9.55	10.50
	2100	Recycled pavement, at plant, ratio old: new, 70:30					19.15			19.15	21
	2120	Ratio old: new, 30:70					23.50			23.50	26
112	0010	CALCIUM CHLORIDE Delivered, 100 lb. bags, truckload lots				Ton	310			310	340
	0200	Solution, 4 lb. flake per gallon, tank truck delivery				Gal.	.62			.62	.68
116	0010	COLD LAID ASPHALT PAVEMENT 0.5 gal. asphalt/S.Y. per in. depth									
	0020	Well graded granular aggregate									
	0100	Blade mixed in windrows, spread & compacted 4" course	B-90A	1,600	.035	S.Y.	3.67	.78	.92	5.37	6.25
	0200	Traveling plant mixed in windrows, compacted 4" course	B-90B	3,000	.016		3.67	.35	.46	4.48	5.10
	0300	Rotary plant mixed in place, compacted 4" course	"	3,500	.014		3.67	.30	.40	4.37	4.95
	0400	Central stationary plant, mixed, compacted 4" course	B-36	7,200	.006		7.35	.12	.15	7.62	8.40
120	0010	CONCRETE PAVEMENT Including joints, finishing, and curing									
	0020	Fixed form, 12' pass, unreinforced, 6" thick	B-26	3,000	.029	S.Y.	13.50	.62	.60	14.72	16.50
	0030	7" thick		2,850	.031		16.10	.65	.63	17.38	19.45
	0100	8" thick		2,700	.033		18.15	.69	.66	19.50	22
	0200	9" thick 		2,900	.030		20.50	.64	.62	21.76	24
	0300	10" thick		2,100	.042		22.50	.89	.85	24.24	27
	0400	12" thick		1,800	.049		27	1.04	.99	29.03	32
	0500	15" thick		1,500	.059		33.50	1.24	1.19	35.93	40.50
	0510	For small irregular areas, add						100%		100%	
	0600	For continuous welded steel reinforcement over 10' wide, add				S.Y.				4.30	
	0610	Under 10' wide, add								6.45	
	0700	Finishing, broom finish small areas	2 Cefi	135	.119			2.76		2.76	4.13
	0730	Transverse expansion joints, incl. premolded bit. jt. filler	C-1	150	.213	L.F.	1	4.82	.18	6	8.95
	0740	Transverse construction joint using bulkhead	"	73	.438	"	1.45	9.90	.38	11.73	17.70
	0750	Longitudinal joint tie bars, grouted	B-23	70	.571	Ea.	2.25	11.10	8.40	21.75	29.50
	1000	Curing, with sprayed membrane by hand	2 Clab	1,500	.011	S.Y.	.15	.20		.35	.49

B-29

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 1 of 1

Alternative C: Incineration

Contaminated Soil Handling

DESIGNED BY RRL DATE 9/1

CHECKED BY RDB DATE 9/1

Rent 1-80 hp 1½ yd³ front-end loader to move Contaminated soil within the storage area and out for the clean front-end loader

time ~ 15 months

Loader = \$3475/month

O&M = \$10.85/hr

Rent 1-100 hp 2 yd³ front end loader to load Contaminated Soil into incinerator

Loader = \$3575/month

O&M = \$11.90/month

$$\text{Total Cost} = 15\text{ months}(\$3475/\text{month} + \$3575/\text{month}) + 15\text{ months}\left(\frac{30\text{ days}}{\text{month}}\right)\left(\frac{24\text{ hr}}{\text{day}}\right)(0.8\text{ utilization})(\$10.85 + 11.90)$$

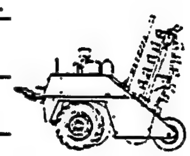
$$= \$302,310 \sim \$303,000$$

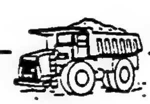
$$\boxed{\text{Total Cost} = \$303,000}$$

CALCULATIONS KE Form No. E-8 Rev. 12-89

016 400 | Equipment Rental

			UNIT	HOURLY OPER. COST	RENT PER DAY	RENT PER WEEK	RENT PER MONTH	CREW EQUIPMENT COST	
408	3400	29,000 lb.	Ea.	11.15	480	1,435	4,300	376.20	408
	3410	Rotary mower, brush, 60", with tractor		7.95	242	725	2,175	208.60	
	3450	Scrapers, towed type, 7 to 9 C.Y. capacity		2.70	76.50	230	690	67.60	
	3500	12 to 17 C.Y. capacity		5.50	235	705	2,125	185	
	3550	Self-propelled, 4 x 4 drive, 2 engine, 14 C.Y. capacity		55.70	1,750	5,275	15,800	1,501	
	3600	1 engine, 24 C.Y. capacity		67.70	2,100	6,265	18,800	1,795	
	3650	Self-loading, 11 C.Y. capacity		24.50	715	2,145	6,425	625	
	3700	22 C.Y. capacity		30.70	1,100	3,325	9,975	910.60	
	3710	Screening plant 110 hp. w / 5' x 10'screen		15	395	1,200	3,600	360	
	3720	5' x 16' screen		16	465	1,400	4,200	408	
	3850	Shovels, see Cranes division 016-460							
	3860	Shovel front attachment, mechanical, 1/2 C.Y.	Ea.	.90	70	210	630	49.20	
	3870	3/4 C.Y.		3.30	112	335	1,000	93.40	
	3880	1 C.Y.		3.55	170	510	1,525	130.40	
	3890	1-1/2 C.Y.		3.95	193	580	1,750	147.60	
	3910	3 C.Y.		7.30	355	1,070	3,200	272.40	
	3950	Stump chipper, 18" deep, 30 H.P.		1.60	243	730	2,200	158.80	
	4110	Tractor, crawler, with bulldozer, torque converter, diesel 75 H.P.		9.95	320	960	2,875	271.60	
	4150	105 H.P.		13.55	490	1,475	4,425	403.40	
	4200	140 H.P.		15.75	585	1,755	5,275	477	
	4260	200 H.P.		27.45	1,000	3,000	9,000	819.60	
	4310	300 H.P.		36.45	1,175	3,520	10,600	995.60	
	4360	410 H.P.		43.25	1,525	4,555	13,700	1,257	
	4380	700 H.P.		87.85	3,425	10,290	30,900	2,761	
	4400	Loader, crawler, torque conv., diesel, 1-1/2 C.Y., 80 H.P.		11.40	430	1,290	3,875	349.20	
	4450	1-1/2 to 1-3/4 C.Y., 95 H.P.		13.55	440	1,325	3,975	373.40	
	4510	1-3/4 to 2-1/4 C.Y., 130 H.P.		17.30	555	1,670	5,000	472.40	
	4530	2-1/2 to 3-1/4 C.Y., 190 H.P.		27.70	940	2,815	8,450	784.60	
	4560	4-1/2 to 5 C.Y., 275 H.P.		39.05	1,300	3,890	11,700	1,090	
	4610	Tractor loader, wheel, torque conv., 4 x 4, 1 to 1-1/4 C.Y., 65 H.P.		8.45	260	780	2,350	223.60	
	4620	1-1/2 to 1-3/4 C.Y., 80 H.P.		10.85	385	1,155	3,475	317.80	
	4650	1-3/4 to 2 C.Y., 100 H.P.		11.90	400	1,195	3,575	334.20	
	4710	2-1/2 to 3-1/2 C.Y., 130 H.P.		17.10	500	1,495	4,475	435.80	
	4730	3 to 4-1/2 C.Y., 170 H.P.		20.25	785	2,350	7,050	632	
	4760	5-1/4 to 5-3/4 C.Y., 270 H.P.		37.20	1,025	3,080	9,250	913.60	
	4810	7 to 8 C.Y., 375 H.P.		54.50	1,350	4,070	12,200	1,250	
	4870	12-1/2 C.Y., 690 H.P.		112	2,475	7,420	22,300	2,380	
	4880	Wheeled, skid steer, 10 C.F., 30 H.P. gas		4.50	100	300	900	96	
	4890	1 C.Y., 78 H.P., diesel		6.20	320	965	2,900	242.60	
	4900	Trencher, chain, boom type, gas, operator walking, 12 H.P.		1.80	112	335	1,000	81.40	
	4910	Operator riding, 40 H.P.		5.90	233	700	2,100	187.20	
	5000	Wheel type, diesel, 4' deep, 12" wide		12.80	450	1,350	4,050	372.40	
	5100	Diesel, 6' deep, 20" wide		14.35	675	2,025	6,075	519.80	
	5150	Ladder type, diesel, 5' deep, 8" wide		8.70	315	950	2,850	259.60	
	5200	Diesel, 8' deep, 16" wide		16.40	550	1,645	4,925	460.20	
	5210	Tree spade, self-propelled		5.35	460	1,375	4,125	317.80	
	5250	Truck, dump, tandem, 12 ton payload		16.50	320	965	2,900	325	
	5300	Three axle dump, 16 ton payload		18.45	420	1,255	3,775	398.60	
	5350	Dump trailer only, rear dump, 16-1/2 C.Y.		3.20	153	460	1,375	117.60	
	5400	20 C.Y.		3.20	155	465	1,400	118.60	
	5450	Flatbed, single axle, 1-1/2 ton rating		10.40	125	375	1,125	158.20	
	5500	3 ton rating		10.45	128	385	1,150	160.60	
	5550	Off highway rear dump, 25 ton capacity		18.30	750	2,250	6,750	596.40	
	5600	35 ton capacity		29.50	1,150	3,480	10,400	932	
	6000	Vibratory plow, 25 H.P., walking		1.25	117	350	1,050	80	
420	0010	GENERAL EQUIPMENT RENTAL R016-410							420
	0150	Aerial lift, scissor type, to 15' high, 1000 lb. cap., electric	Ea.	1.08	83.50	250	750	58.65	





GENERAL REQUIREMENTS 1

B-31

ICF KAISER ENGINEERS

Job No. 04302403006

Sheet 1 of 1

Alternative C: Incineration

Mobile Incineration Costs

DESIGNED BY RRL DATE 9/1/9

CHECKED BY [illegible] DATE 9/1/9

1) Contractor Mobilization

Mobilization costs are typically charged by the vendor. Included in these costs are transportation of the incinerator to the site, equipment set up, and equipment check-out and operation to verify that the unit is operating properly.

$\boxed{\text{Cost} = \$500{,}000}$

2) Trial Burn

Trial burns are performed to establish the range of operating parameters to meet regulatory compliance. Time to complete a trial burn is approximately 2 months. Costs can include chemicals necessary to demonstrate DREs.

Cost = \$250,000 – $\boxed{\$750{,}000}$/trial burn

3) Mobile Rotary Kiln Incineration

The incineration system consists of the soil feed system, Primary Kiln, secondary Kiln, Ash removal system, Air quality control system, instrumentation, controls, and air monitoring equipment. There are no capital costs, all costs are based on the mass of soil treated

Cost = $\boxed{\$300}$ – \$500/ton

4) Demobilization

Demobilization consists of decontamination and tear down of the equipment after soil treatment. The time required for demobilization is 1-2 months

$\boxed{\text{Cost} = \$500{,}000}$

Source: Mike Duke - DRE Environmental Services (615) 373-1373

CALCULATIONS KE Form No. E-6 Rev. 12-89

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 1 of 1

Alternative C: Incineration
Daily influent/effluent monitoring for mobile incinerator

DESIGNED BY RRL DATE 9/1/9

CHECKED BY RJB DATE 9/1/9

1) Daily Composite of Influent

-A sample will be analyzed for explosives, TAL/TCL, ash content, and ultimate analysis (C, H, N, Cl, S) to determine a daily composite of soil entering the incineration unit.

Cost: Explosives - $320
TAL/TCL - $1,250
Ultimate - $120
Ash Content - $20
$1710/day

2) Daily Composite of Effluent

-A sample will be analyzed for explosives, TCLP, TAL Metals, ignitability, corrosivity, and reactivity (I,C,R) to determine the composition of the treated soil.

Cost: Explosives - $320
TCLP - $700
TAL Metals - $301
I,C,R - $386
$1707/day

Source: ESE, Gainsville, FL

3) Total Cost

-Incinerator will operate 80% of the time for 57 weeks

Time = (57 weeks)(7 days/week) = 399 days

Cost = (399 days)($1710/day + $1707/day) = $1,363,383

$\boxed{\sim \$1,370,000}$

Alternative D: Windrow Composting and Bioslurry

Site Work

DESIGNED BY RRL	DATE 9/1/94
CHECKED BY RDE	DATE 9/1/94

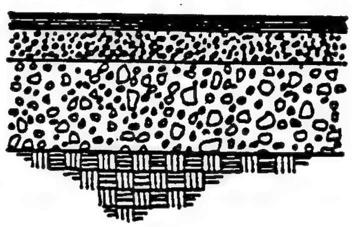
1) Roadway for heavy equipment to biotreatment area

Size 200 ft × 24 ft wide   9" Gravel
3½" Pavement

Unit Cost = \$68.50/ft

Cost = (200 ft)(\$68.50/ft) = \$13,700 ~ $\boxed{\$14,000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89



The Bituminous Roadway Systems are listed for pavement thicknesses between 3-1/2" and 7" and gravel bases from 3" to 22" in depth. Systems costs are expressed per linear foot for varying widths of two and multi-lane roads. Earth moving is not included. Granite curbs and line painting are added as required system components.

System Components	QUANTITY	UNIT	COST PER L.F. MAT.	INST.	TOTAL
SYSTEM 12.5-111-1050					
BITUM. ROADWAY, TWO LANES, 3-1/2" TH. PVMT., 3" TH. GRAVEL BASE,24' WIDE					
Compact subgrade, 4 passes	2.670	S.Y.		1.92	1.92
Bank gravel, 2 mi haul, dozer spread	.250	C.Y.	1.03	1.12	2.15
Compaction granular material to 98%	.250	C.Y.		.11	.11
Grading, fine grade, 3 passes with grader	2.670	S.Y.		4.55	4.55
Bituminous paving, binder course, 2-1/2" thick	2.670	S.Y.	9.72	2.43	12.15
Bituminous paving, wearing course, 1" thick	2.670	S.Y.	4.22	1.31	5.53
Curbs, granite, split face, straight, 5" x 16"	2.000	L.F.	28.20	9.84	38.04
Painting lines, reflectorized, 4" wide	1.000	L.F.	.31	.13	.44
TOTAL			43.48	21.41	64.89

12.5-111	Bituminous Roadways	COST PER L.F. MAT.	INST.	TOTAL
1050	Bitum. roadway, two lanes, 3-1/2" th. pvmt., 3" th. gravel base, 24' wide	43.50	21.50	65
1100	28' wide	46.50	22.50	69
1150	32' wide	48.50	24	72.50
1300	9" th. gravel base, 24' wide	45.50	23	68.50
1350	28' wide	48.50	25.50	74
1400	32' wide	51.50	27.50	79
1550	4" th. pvmt., 4" th. gravel base, 24' wide	45.50	21	66.50
1600	28' wide	48.50	23	71.50
1650	32' wide	51.50	25	76.50
1800	10" th. gravel base, 24' wide	48	23.50	71.50
1850	28' wide	51	26	77
1900	32' wide	54	28	82
2050	4" th. pvmt., 5" th. gravel base, 24' wide	46.50	22	68.50
2100	28' wide	49.50	24	73.50
2150	32' wide	52.50	26	78.50
2300	12" th. gravel base, 24' wide	49	25	74
2350	28' wide	52.50	27.50	80
2400	32' wide	55.50	30	85.50
2550	4-1/2" th. pvmt., 5" th. gravel base, 24' wide	48.50	22	70.50
2600	28' wide	51.50	24	75.50
2650	32' wide	55	26	81
2800	13" th. gravel base, 24' wide	51	25.50	76.50
2850	28' wide	55	28	83
2900	32' wide	58.50	30.50	89
3050	5" th. pvmt., 6" th. gravel base, 24' wide	50.50	23	73.50
3100	28' wide	54	25	79
3150	32' wide	58	27	85
3300	14" th. gravel base, 24' wide	53.50	26	79.50
3350	28' wide	57.50	29	86.50
3400	32' wide	61.50	31.50	93
3550	5-1/2" th. pvmt., 7" th. gravel base, 24' wide	53	23.50	76.50
3600	28' wide	57	26	83

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-35

ICF KAISER ENGINEERS

Job No. 04302463
Sheet 1 of 2

Alternative D: Windrow Composting
Bioslurry
Contaminated Soil Excavation

DESIGNED BY RRL DATE 9/1/..
CHECKED BY RJB DATE 9/1/9..

1) Clear Top 2" of Soil and Stockpile

Area = $(18,500 yd^3)(27 ft^3/yd^3)(1/10 ft\ excavation) = 49,950 ft^2$

Volume = $(49,950 ft^2)(2 inches)(\frac{1 foot}{12 in})(\frac{1 yd^3}{27 ft^3}) = 308 yd^3$

Unit Cost = $\$1.14/yd^3$

Cost = $(308 yd^3)(\$1.14/yd^3) = \$351 \sim \$400$

Note: Must analyze top soil to determine if it is non-hazardous

2) Confirmatory Sampling

Approximately 5000 samples for topsoil and subsurface confirmatory samples with test kits

Unit Cost = \$50/sample

Cost = (5000 Samples)(\$50/sample) = \$250,000

3) Contaminated Soil Excavation

Excavation of the contaminated soil will be performed with a $1\frac{1}{2} yd^3$ backhoe. Add 15% for loading onto trucks

Unit Cost = $(\$1.65/yd^3)(1.15) = \$1.90/yd^3$

Cost = $(18,500 yd^3)(\$1.90/yd^3) = \$35,150 \sim \$36,000$

4) Contaminated Soil Hauling

Soil will be hauled with $12 yd^3$ dump trucks
- assume a 5 mile round trip

Unit Cost = $\$6.95/yd^3$

Cost = $(18,500 yd^3)(1.2\ Bulking)(\$6.95/yd^3) = \$154,290$

$\sim \$155,000$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Ref.	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	Ref.
		021 100 | Site Clearing										
116	1700	24" to 36" diameter, softwood	B-10M	100	.120	Ea.		2.71	9.95	12.66	15.15	116
	1750	Hardwood		50	.240			5.40	19.90	25.30	30.50	
	1800	36" to 48" diameter, softwood		70	.171			3.87	14.20	18.07	21.50	
	1850	Hardwood		35	.343			7.75	28.50	36.25	43.50	
		021 140 | Stripping										
144	0010	STRIPPING Topsoil, and stockpiling, sandy loam										144
	0020	200 H.P. dozer, ideal conditions	B-10B	2,300	.005	C.Y.		.12	.36	.48	.57	
	0100	Adverse conditions	•	1,150	.010			.24	.71	.95	1.14	
	0200	300 HP dozer, ideal conditions	B-10M	3,000	.004			.09	.33	.42	.51	
	0300	Adverse conditions	•	1,650	.007			.16	.60	.76	.91	
	0400	400 HP dozer, ideal conditions	B-10X	3,900	.003			.07	.32	.39	.46	
	0500	Adverse conditions	•	2,000	.006			.14	.63	.77	.90	
	0600	Clay, dry and soft, 200 HP dozer, ideal conditions	B-10B	1,600	.008			.17	.51	.68	.82	
	0601	Strip topsoil, clay, dry & soft, 200 HP dozer, ideal conditions		1,600	.008			.17	.51	.68	.82	
	0700	Adverse conditions		800	.015			.34	1.02	1.36	1.65	
	1000	Medium hard, 300 HP dozer, ideal conditions	B-10M	2,000	.006			.14	.50	.64	.76	
	1100	Adverse conditions	•	1,100	.011			.25	.91	1.16	1.38	
	1200	Very hard, 400 HP dozer, ideal conditions	B-10X	2,600	.005			.10	.48	.58	.69	
	1300	Adverse conditions	•	1,340	.009			.20	.94	1.14	1.34	
		021 150 | Selective Clearing										
154	0010	SELECTIVE CLEARING										154
	1000	Stump removal on site by hydraulic backhoe, 1-1/2 C.Y.										
	1050	8" to 12" diameter	B-30	33	.727	Ea.		15.45	45	60.45	73.50	
	1100	14" to 24" diameter		25	.960			20.50	59	79.50	96.50	
	1150	26" to 36" diameter		16	1.500			32	92.50	124.50	151	
	1151	Stump removal, 19" to 24" diameter		16	1.500			32	92.50	124.50	151	
	2000	Remove selective trees, on site using chain saws and chipper,										
	2050	not incl. stumps, up to 6" diameter	B-7	18	2.667	Ea.		54	59.50	113.50	151	
	2100	8" to 12" diameter		12	4			81	89.50	170.50	225	
	2150	14" to 24" diameter		10	4.800			97	107	204	271	
	2200	26" to 36" diameter		8	6			121	134	255	340	
	2300	Machine load, 2 mile haul to dump, 12" diam. tree, add								40	60	
		021 200 | Structure Moving										
204	0010	MOVING BUILDINGS One day move, up to 24' wide										204
	0020	Reset on new foundation, patch & hook-up, average move				Total					8,500	
	0040	Wood or steel frame bldg., based on ground floor area	B-4	185	.259	S.F.		5.05	2.35	7.40	10.55	
	0060	Masonry bldg., based on ground floor area	•	137	.350			6.80	3.17	9.97	14.25	
	0200	For 24' to 42' wide, add									15%	
	0220	For each additional day on road, add	B-4	1	48	Day		935	435	1,370	1,950	
	0240	Construct new basement, move building, 1 day										
	0300	move, patch & hook-up, based on ground floor area	B-3	155	.310	S.F.	5.30	6.35	10.20	21.85	27	
		021 400 | Dewatering										
404	0010	DEWATERING Excavate drainage trench, 2' wide, 2' deep	B-11C	90	.178	C.Y.		3.85	2.22	6.07	8.45	404
	0100	2' wide, 3' deep, with backhoe loader	•	135	.119			2.57	1.48	4.05	5.65	
	0200	Excavate sump pits by hand, light soil	1 Clab	7.10	1.127			21.50		21.50	34	
	0300	Heavy soil	•	3.50	2.286			43.50		43.50	69	
	0500	Pumping 8 hr., attended 2 hrs. per day, including 20 L.F.										
	0550	of suction hose & 100 L.F. discharge hose										
	0600	2" diaphragm pump used for 8 hours	B-10H	4	3	Day		67.50	7.80	75.30	114	
	0620	Add per additional pump							30	26	33	
	0650	4" diaphragm pump used for 8 hours	B-10I	4	3			67.50	19.90	87.40	127	
	0670	Add per additional pump							63	68	69	

B-37

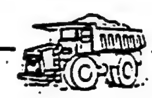
022 200 | Excav./Backfill/Compact.

		022 200 Excav./Backfill/Compact.	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
234	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04	234
	4600	Maximum	"	15,100	.002	"		.04		.04	.07	
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25	
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25	
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14	
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73	
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27	
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4	
	5460	4 mile round trip	↓	200	.040	↓		.79	2.98	3.77	4.49	
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer										
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88	
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20	
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05	
	5820	300' haul	↓	200	.060	↓		1.35	4.98	6.33	7.60	
238	0010	EXCAVATING, BULK BANK MEASURE Common earth piled (R022-240)										238
	0020	For loading onto trucks, add								15%	15%	
	0050	For mobilization and demobilization, see division 022-274 (R022-250)										
	0100	For hauling, see division 022-266										
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.62	.88	1.50	1.91	
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65	
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53	
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77	
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82	
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89	
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr.	B-12G	160	.100			2.31	2.82	5.13	6.65	
	0550	1 C.Y. cap. = 35 C.Y./hr.	B-12H	280	.057			1.32	1.91	3.23	4.12	
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50	
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1001	3/4 C.Y. cap. = 35 C.Y./hr.	↓	280	.057			1.32	1.67	2.99	3.86	
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69	
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71	
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44	
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23	
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23	
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1	
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84	
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20	
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12	
	1601	3 C.Y. cap. = 100 C.Y./hr.	"	1,100	.011			.25	.40	.65	.82	
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96	
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15	
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11	
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44	
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69	
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28	
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18	
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87	
	4000	For soft soil or sand, deduct								15%	15%	
	4100	For heavy soil or stiff clay, add								60%	60%	
	4200	For wet excavation with clamshell or dragline, add								100%	100%	
	4250	All other equipment, add								50%	50%	
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20	
	4450	Maximum	"	60	.267	↓		6.15	8.90	15.05	19.25	
	8000	For hauling excavated material, see div. 022-266										
242	0010	EXCAVATING, BULK, DOZER Open site										242
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56	

13-38

022 200 | Excav./Backfill/Compact.

			Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
262	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
266	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-39

ICF KAISER ENGINEERS

Job No. 0430240300

Sheet 2 of 2

Alternative D: Windrow Composting / Bioslurry

Contaminated Soil Excavation

DESIGNED BY RRL DATE 11/8/

CHECKED BY TDW DATE 11/8/9

5) Confirmatory Sampling

10% of the TNT and RDX immunoassay samples will be sent to a lab for confirmatory HPLC analysis. Samples will be collected at the bottom of each excavation. Add 15% to the number of samples collected to account for duplicates and blanks.

Unit Cost = \$350/sample : Includes analysis and Sample QA/QC

Samples = (5000 Immunoassays)(0.10)(1.15) = 575 samples

Cost = (575 samples)(\$350/sample) = \$201,250 ~ \$202,000

Source: ESE Laboratories, Gainesville, FL

Total Cost = \$400 + \$250,000 + \$36,000 + \$155,000 + \$202,000 = \$643,400 ~ \$643,000

Total Cost = \$643,000

CALCULATIONS KE Form No. E-6 Rev. 12-89

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 1 of 2

Alternative D: Windrow Composting

Clean Soil Backfill

DESIGNED BY RRL DATE 9/1/9[illegible]

CHECKED BY [illegible] DATE 9/1/9[illegible]

Disposal Area Size Calculations

Volume of Soil = $(18{,}500\ yd^3)(1.2\ \text{Bulking}) = 22{,}200\ yd^3$

60% Bulking = $(22{,}200\ yd^3)(60\%) = 13{,}320\ yd^3 \approx 13{,}300$

10% Daily Cover = $(22{,}200 + 13{,}300)(10\%) = \underline{3{,}500\ yd^3}$

$39{,}000\ yd^3$

$\sim 1{,}053{,}000\ ft^3$

Depth = 10 ft

Surface Area = $105{,}000\ ft^2$ or 325×325

Add 3 ft on edges for liner

Total Volume = $328 \times 328 \times 13 = 1{,}399{,}000 \approx 52{,}000\ yd^3$

Total Surface Area = $328 \times 328 = 108{,}000\ ft^2 \approx 2.5$ acres

1) **Borrow Area Clearing**

Clean area to be used as on-site Landfill. Reduce cost by 40% because trees will be burned at OBG, not chipped

Area = 2.5 acres

Unit Cost = $(\$2700/ac)(60\%) = \$1620/ac$

Hauling to OBG

Hauling will be a 5 mile round trip with a $12\ yd^3$ dumptruck

Assume $0.5\ ft^3$ of material for every ft^2 cleared

Unit Cost = $(\$6.95/yd^3)\left(\frac{1\ yd^3}{27\ ft^3}\right)\left(\frac{0.5\ ft^3}{1\ ft^2}\right)\left(\frac{43560\ ft^2}{acre}\right) = \$5606/acre$

Cost = $(2.5\ acres)(\$1620/acre + \$5606/acre) = \$18{,}065$

$\sim \$18{,}000$

021 100 | Site Clearing

		Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	1994 Bare Costs Labor	1994 Bare Costs Equip.	1994 Bare Costs Total	Total Incl O&P	
104	0010	CLEAR AND GRUB Light, trees to 6" diam., cut & chip	B-7	1	48	Acre		970	1,075	2,045	2,700	104
	0150	Grub stumps and remove	B-30	2	12			255	740	995	1,200	
	0160	Clear & grub brush & stumps	•	.58	41.379			880	2,550	3,430	4,150	
	0200	Medium, trees to 12" diam., cut & chip	B-7	.70	68.571			1,375	1,525	2,900	3,850	
	0250	Grub stumps and remove	B-30	1	24			510	1,475	1,985	2,400	
	0260	Clear & grub dense brush & stumps	•	.47	51.064			1,075	3,150	4,225	5,125	
	0300	Heavy, trees to 24" diam., cut & chip	B-7	.30	160			3,225	3,575	6,800	9,025	
	0350	Grub stumps and remove	B-30	.50	48			1,025	2,950	3,975	4,825	
	0400	If burning is allowed, reduce cut & chip									40%	
	3000	Chipping stumps, to 18" deep, 12" diam.	B-86	20	.400	Ea.		9.75	7.95	17.70	23.50	
	3040	18" diameter		16	.500			12.20	9.95	22.15	29.50	
	3080	24" diameter		14	.571			13.90	11.35	25.25	34	
	3100	30" diameter		12	.667			16.25	13.25	29.50	39.50	
	3120	36" diameter		10	.800			19.50	15.90	35.40	47.50	
	3160	48" diameter		8	1			24.50	19.85	44.35	59.50	
	5000	Tree thinning, feller buncher, conifer										
	5080	Up to 8" diameter	B-93	240	.033	Ea.		.81	1.42	2.23	2.80	
	5120	12" diameter		160	.050			1.22	2.13	3.35	4.21	
	5240	Hardwood, up to 4" diameter		240	.033			.81	1.42	2.23	2.80	
	5280	8" diameter		180	.044			1.08	1.89	2.97	3.74	
	5320	12" diameter		120	.067			1.62	2.84	4.46	5.60	
	7000	Tree removal, congested area, aerial lift truck										
	7040	8" diameter	B-85	7	5.714	Ea.		115	110	225	300	
	7080	12" diameter		6	6.667			135	128	263	350	
	7120	18" diameter		5	8			162	154	316	425	
	7160	24" diameter		4	10			202	193	395	525	
	7240	36" diameter		3	13.333			269	257	526	705	
	7280	48" diameter		2	20			405	385	790	1,050	
108	0010	CLEARING Brush with brush saw	A-1	.25	32	Acre		610	234	844	1,225	108
	0100	By hand	•	.12	66.667			1,275	485	1,760	2,525	
	0300	With dozer, ball and chain, light clearing	B-11A	2	8			173	410	583	720	
	0400	Medium clearing	•	1.50	10.667			231	545	776	960	
	0500	With dozer and brush rake, light	B-11B	1	16			345	1,025	1,370	1,675	
	0550	Medium brush to 4" diameter		.60	26.667			580	1,725	2,305	2,775	
	0600	Heavy brush to 4" diameter		.40	40			865	2,575	3,440	4,175	
	1000	Brush mowing, tractor w/rotary mower, no removal										
	1020	Light density	B-84	2	4	Acre		97.50	104	201.50	264	
	1040	Medium density		1.50	5.333			130	139	269	350	
	1080	Heavy density		1	8			195	209	404	530	
116	0010	FELLING TREES & PILING With tractor, large tract, firm										116
	0020	level terrain, no boulders, less than 12" diam. trees										
	0300	300 HP dozer, up to 400 trees/acre, 0 to 25% hardwoods	B-10M	.75	16	Acre		360	1,325	1,685	2,000	
	0340	25% to 50% hardwoods		.60	20			450	1,650	2,100	2,525	
	0370	75% to 100% hardwoods		.45	26.667			600	2,225	2,825	3,350	
	0400	500 trees/acre, 0% to 25% hardwoods		.60	20			450	1,650	2,100	2,525	
	0440	25% to 50% hardwoods		.48	25			565	2,075	2,640	3,150	
	0470	75% to 100% hardwoods		.36	33.333			750	2,775	3,525	4,225	
	0500	More than 600 trees/acre, 0 to 25% hardwoods		.52	23.077			520	1,925	2,445	2,900	
	0540	25% to 50% hardwoods		.42	28.571			645	2,375	3,020	3,600	
	0570	75% to 100% hardwoods		.31	38.710			875	3,200	4,075	4,875	
	0900	Large tract clearing per tree										
	1500	300 HP dozer, to 12" diameter, softwood	B-10M	320	.038	Ea.		.85	3.11	3.96	4.73	
	1550	Hardwood		100	.120			2.71	9.95	12.66	15.15	
	1600	12" to 24" diameter, softwood		200	.060			1.35	4.98	6.33	7.60	
	1650	Hardwood		80	.150			3.39	12.45	15.84	18.95	

13-42

022 200 | Excav./Backfill/Compact.

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
262	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
266	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-43

2) Borrow Area Excavation

Excavation will be performed with a $1\frac{1}{2}\,yd^3$ backhoe

Unit Cost = $(\$1.65/yd^3)$(1.15 for loading onto Trucks) = $\$1.90/yd^3$

Cost = $(52{,}000\,yd^3)(\$1.90/yd^3) = \$98{,}800 \sim \$99{,}000$

3) Borrow Material Hauling

Haul backfill with $12\,yd^3$ dumptrucks

Unit Cost = $\$6.95/yd^3$

Cost = $(22{,}200\,yd^3)(\$6.95/yd^3) = \$154{,}290 \sim \$155{,}000$

4) Earth Backfilling

Includes 200 hp Bulldozer, Waterwagon, Compaction Roller

Unit Cost = $\$3.03/yd^3$

Cost = $(22{,}200\,yd^3)(\$3.03/yd^3) = \$67{,}266 \sim \$68{,}000$

5) Reseeding

The Reseeding will be conducted using hydro or air seeding with mulch and fertilizer

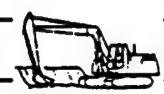
Area = $(18{,}500\,yd^3)\left(\frac{27\,ft^3}{yd^3}\right)(1/10\,ft) = 49{,}950\,ft^2$

Unit Cost = $\$39/1000\,ft^2$

Cost = $(49{,}950\,ft^2)(\$39/1000\,ft^2) = \$1948 \sim \$2000$

Total Cost = $\$18{,}000 + \$99{,}000 + \$155{,}000 + \$68{,}000 + \$2000 = \boxed{\$342{,}000}$

022 200 | Excav./Backfill/Compact.

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
234	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04
	4600	Maximum	•	15,100	.002	•		.04		.04	.07
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4
	5460	4 mile round trip		200	.040			.79	2.98	3.77	4.49
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer									
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05
	5820	300' haul		200	.060			1.35	4.98	6.33	7.60
238	0010	EXCAVATING, BULK BANK MEASURE Common earth piled (R022 -240)									
	0020	For loading onto trucks, add								15%	15%
	0050	For mobilization and demobilization, see division 022-274 (R022 -250)									
	0100	For hauling, see division 022-266									
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.62	.88	1.50	1.91
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr. 	B-12G	160	.100			2.31	2.82	5.13	6.65
	0550	1 C.Y. cap. = 35 C.Y./hr.	B-12H	280	.057			1.32	1.91	3.23	4.12
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86
	1001	3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12
	1601	3 C.Y. cap. = 100 C.Y./hr.	•	1,100	.011			.25	.40	.65	.82
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87
	4000	For soft soil or sand, deduct								15%	15%
	4100	For heavy soil or stiff clay, add								60%	60%
	4200	For wet excavation with clamshell or dragline, add								100%	100%
	4250	All other equipment, add								50%	50%
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20
	4450	Maximum	•	60	.267			6.15	8.90	15.05	19.25
	8000	For hauling excavated material, see div. 022-266									
242	0010	EXCAVATING, BULK, DOZER Open site									
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56

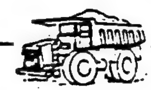
SITE WORK 2

B-45

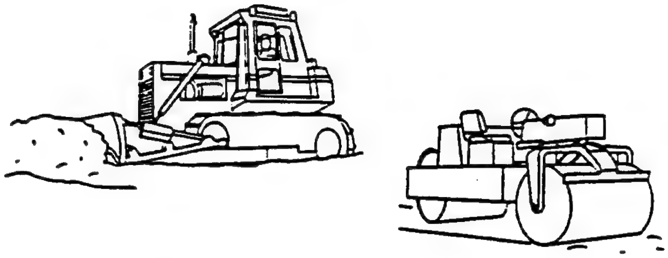
2 SITE WORK

022 200 | Excav./Backfill/Compact.

			Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
262	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
266	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		150	.053			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



B-46



The Common Earth Backfilling System includes: a bulldozer to place and level backfill in specified lifts: compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Common Earth Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-724-1000					
EARTH BACKFILL, 75 HP DOZER & ROLLER, 50' HAUL, 4"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, common earth, from stockpile	1.000	C.Y.	.31	.43	.74
Water wagon, rent per day	.004	Hr.	.27	.12	.39
Compaction, roller, 4" lifts, 2 passes	.035	Hr.	.65	1.84	2.49
Total			1.23	2.39	3.62

12.1-724	Common Earth Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Earth backfill, 75 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.23	2.39	3.62
1050	4 passes	1.88	4.23	6.11
1100	8" lifts, 2 passes	.91	1.50	2.41
1150	4 passes	1.23	2.39	3.62
1200	150' haul, 4" lifts, 2 passes	1.53	2.82	4.35
1250	4 passes	2.18	4.66	6.84
1300	8" lifts, 2 passes	1.21	1.93	3.14
1350	4 passes	1.53	2.82	4.35
1400	300' haul, 4" lifts, 2 passes	1.83	3.23	5.06
1450	4 passes	2.48	5.05	7.53
1500	8" lifts, 2 passes	1.51	2.34	3.85
1550	4 passes	1.83	3.23	5.06
1600	105 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.28	2.30	3.58
1650	4 passes	1.93	4.14	6.07
1700	8" lifts, 2 passes	.96	1.41	2.37
1750	4 passes	1.28	2.30	3.58
1800	150' haul, 4" lifts, 2 passes	1.65	2.65	4.30
1850	4 passes	2.30	4.49	6.79
1900	8" lifts, 2 passes	1.33	1.76	3.09
1950	4 passes	1.65	2.65	4.30
2000	300' haul, 4" lifts, 2 passes	1.99	2.97	4.96
2050	4 passes	2.64	4.81	7.45
2100	8" lifts, 2 passes	1.67	2.08	3.75
2150	4 passes	1.99	2.97	4.96
2200	200 HP dozer & roller compactors, 150' haul, 4" lifts, 2 passes	1.70	1.55	3.25
2250	4 passes	2.31	2.60	4.91
2300	8" lifts, 2 passes	1.40	1.03	2.43
2350	4 passes	1.70	1.55	3.25
2600	300' haul, 4" lifts, 2 passes	2.11	1.74	3.85
2650	4 passes	2.72	2.79	5.51
2700	8" lifts, 2 passes	1.81	1.22	3.03
2750	4 passes	2.11	1.74	3.85

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-47

2 SITE WORK

		029 200 | Soil Preparation	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
204	6000	Tilling topsoil, 20 HP tractor, disk harrow, 2" deep	B-66	50,000	.001	S.Y.					.01	204
	6050	4" deep		40,000	.001						.02	
	6100	6" deep		30,000	.001			.01	.01	.02	.02	
	6150	26" rototiller, 2" deep	A-1	1,250	.006			.12	.05	.17	.25	
	6200	4" deep		1,000	.008			.15	.06	.21	.32	
	6250	6" deep		750	.011			.20	.08	.28	.43	
	7000	Lawn maintenance see Division 029-700										
208	0010	PLANT BED PREPARATION										208
	0100	Backfill planting pit, by hand, on site topsoil	2 Clab	18	.889	C.Y.		16.90		16.90	28.50	
	0200	Prepared planting mix	"	24	.667			12.65		12.65	21.50	
	0300	Skid steer loader, on site topsoil	B-62	340	.071			1.44	.28	1.72	2.70	
	0400	Prepared planting mix	"	410	.059			1.20	.23	1.43	2.24	
	1000	Excavate planting pit, by hand, sandy soil	2 Clab	16	1			19		19	32	
	1100	Heavy soil or clay	"	8	2			38		38	64	
	1200	1/2 C.Y. backhoe, sandy soil	B-11C	150	.107			2.31	1.33	3.64	5.25	
	1300	Heavy soil or clay	"	115	.139			3.02	1.74	4.76	6.85	
	2000	Mix planting soil, incl. loam, manure, peat, by hand	2 Clab	60	.267		24	5.05		29.05	35	
	2100	Skid steer loader	B-62	150	.160		24	3.28	.64	27.92	32.50	
	3000	Pile sod, skid steer loader	"	2,800	.009	S.Y.		.18	.03	.21	.33	
	3100	By hand	2 Clab	400	.040			.76		.76	1.28	
	4000	Remove sod, F.E. loader	B-10S	2,000	.006			.14	.16	.30	.39	
	4100	Sod cutter	B-12K	3,200	.005			.12	.26	.38	.48	
	4200	By hand	2 Clab	240	.067			1.27		1.27	2.13	

		029 300 | Lawns & Grasses	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
308	0010	SEEDING Athletic field mix, 8#/M.S.F., push spreader R029 -310	A-1	10	.800	M.S.F.	11.80	15.20	5.85	32.85	45	308
	0100	Tractor spreader	B-66	52	.154		11.80	3.60	3.51	18.91	22.50	
	0200	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	0400	Birdsfoot trefoil, .45#/M.S.F., push spreader	A-1	10	.800		13.95	15.20	5.85	35	47.50	
	0500	Tractor spreader	B-66	52	.154		13.95	3.60	3.51	21.06	25	
	0600	Hydro or air seeding,with mulch & fertil.	B-81	80	.300		28.50	6.30	6.90	41.70	49.50	
	0800	Bluegrass, 4#/M.S.F., common, push spreader	A-1	10	.800		5.05	15.20	5.85	26.10	37.50	
	0900	Tractor spreader	B-66	52	.154		5.05	3.60	3.51	12.16	15.20	
	1000	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		19.15	6.30	6.90	32.35	39	
	1100	Baron, push spreader	A-1	10	.800		10.60	15.20	5.85	31.65	43.50	
	1200	Tractor spreader	B-66	52	.154		10.60	3.60	3.51	17.71	21.50	
	1300	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	1500	Clover, 0.67#/M.S.F., white, push spreader	A-1	10	.800		2.50	15.20	5.85	23.55	34.50	
	1600	Tractor spreader	B-66	52	.154		2.50	3.60	3.51	9.61	12.40	
	1700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		16.65	6.30	6.90	29.85	36.50	
	1800	Ladino, push spreader	A-1	10	.800		4.23	15.20	5.85	25.28	36.50	
	1900	Tractor spreader	B-66	52	.154		4.23	3.60	3.51	11.34	14.30	
	2000	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		18.20	6.30	6.90	31.40	38	
	2200	Fescue 5.5#/M.S.F., tall, push spreader	A-1	10	.800		7.35	15.20	5.85	28.40	40	
	2300	Tractor spreader	B-66	52	.154		7.35	3.60	3.51	14.46	17.70	
	2400	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		22.50	6.30	6.90	35.70	42.50	
	2500	Chewing, push spreader	A-1	10	.800		8.55	15.20	5.85	29.60	41.50	
	2600	Tractor spreader	B-66	52	.154		8.55	3.60	3.51	15.66	19.05	
	2700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		23.50	6.30	6.90	36.70	43.50	
	2900	Crown vetch, 4#/M.S.F., push spreader	A-1	10	.800		38.50	15.20	5.85	59.55	74.50	
	3000	Tractor spreader	B-66	52	.154		38.50	3.60	3.51	45.61	52	
	3100	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		53	6.30	6.90	66.20	76	
	3300	Rye, 10#/M.S.F., annual, push spreader	A-1	10	.800		4.83	15.20	5.85	25.88	37	
	3400	Tractor spreader	B-66	52	.154		4.83	3.60	3.51	11.94	14.95	
	3500	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		18.25	6.30	6.90	31.45	38	

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-48

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 1 of 1

Alternative D: Windrow Composting

Treated Soil Disposal

DESIGNED BY RRL DATE 9/1/9

CHECKED BY [illegible] DATE [illegible]

1) Treated Soil from Storage to On-Site Landfill

Loading of the treated soil into 12yd³ dumptrucks will be performed with a 1½yd³ front end loaders. Trucks will travel a 4 mile round trip.

Unit Costs: Front End Loader = $1.20/yd³

12 yd³ Dump Trucks = $4.54/yd³

$5.74/yd³

Cost = (35,500 yd³)(5.74/yd³) = $203,770 ~ $204,000

2) Backfill and Compact Treated Soil

Backfilling will be performed with a 50' haul, 4" lifts with 4 passes of the compactor; treated soil and daily cover

Unit Cost = $6.07/yd³

Cost = (39,000 yd³)($6.07/yd³) = $236,730 ~ $237,000

Note: Daily cover could be taken from extra soil excavated from the borrow area

Total Cost = $204,000 + $237,000 = $\boxed{\$441,000}$

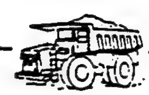
022 200 | Excav./Backfill/Compact.

		022 200 Excav./Backfill/Compact.	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
234	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04
	4600	Maximum	"	15,100	.002	"		.04		.04	.07
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4
	5460	4 mile round trip		200	.040			.79	2.98	3.77	4.49
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer									
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05
	5820	300' haul		200	.060			1.35	4.98	6.33	7.60
238	0010	**EXCAVATING, BULK BANK MEASURE** Common earth piled (R022-240)									
	0020	For loading onto trucks, add								15%	15%
	0050	For mobilization and demobilization, see division 022-274 (R022-250)									
	0100	For hauling, see division 022-266									
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.62	.88	1.50	1.91
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr.	B-12G	160	.100			2.31	2.82	5.13	6.65
	0550	1 C.Y. cap. = 35 C.Y./hr.	B-12H	280	.057			1.32	1.91	3.23	4.12
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86
	1001	3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12
	1601	3 C.Y. cap. = 100 C.Y./hr.	"	1,100	.011			.25	.40	.65	.82
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87
	4000	For soft soil or sand, deduct								15%	15%
	4100	For heavy soil or stiff clay, add								60%	60%
	4200	For wet excavation with clamshell or dragline, add								100%	100%
	4250	All other equipment, add								50%	50%
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20
	4450	Maximum	"	60	.267			6.15	8.90	15.05	19.25
	8000	For hauling excavated material, see div. 022-266									
242	0010	**EXCAVATING, BULK, DOZER** Open site									
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56

B-50

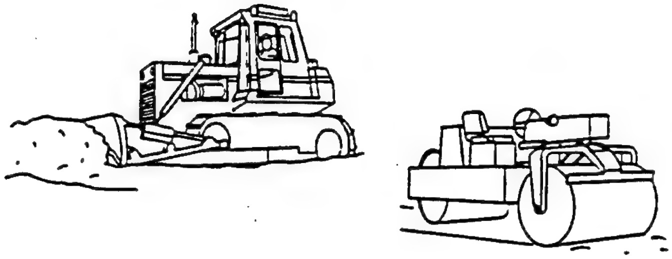
022 200 | Excav./Backfill/Compact.

		Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
252	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-225									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
256	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



B-51

Common Earth Backfill



The Common Earth Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Common Earth Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-724-1000					
EARTH BACKFILL, 75 HP DOZER & ROLLER, 50' HAUL, 4"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, common earth, from stockpile	1.000	C.Y.	.31	.43	.74
Water wagon, rent per day	.004	Hr.	.27	.12	.39
Compaction, roller, 4" lifts, 2 passes	.035	Hr.	.65	1.84	2.49
Total			1.23	2.39	3.62

12.1-724	Common Earth Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Earth backfill,75 HP dozer & roller compactors,50' haul,4" lifts,2 passes	1.23	2.39	3.62
1050	4 passes	1.88	4.23	6.11
1100	8" lifts, 2 passes	.91	1.50	2.41
1150	4 passes	1.23	2.39	3.62
1200	150' haul, 4" lifts, 2 passes	1.53	2.82	4.35
1250	4 passes	2.18	4.66	6.84
1300	8" lifts, 2 passes	1.21	1.93	3.14
1350	4 passes	1.53	2.82	4.35
1400	300' haul, 4" lifts, 2 passes	1.83	3.23	5.06
1450	4 passes	2.48	5.05	7.53
1500	8" lifts, 2 passes	1.51	2.34	3.85
1550	4 passes	1.83	3.23	5.06
1600	105 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.28	2.30	3.58
1650	4 passes	1.93	4.14	6.07
1700	8" lifts, 2 passes	.96	1.41	2.37
1750	4 passes	1.28	2.30	3.58
1800	150' haul, 4" lifts, 2 passes	1.65	2.65	4.30
1850	4 passes	2.30	4.49	6.79
1900	8" lifts, 2 passes	1.33	1.76	3.09
1950	4 passes	1.65	2.65	4.30
2000	300' haul, 4" lifts, 2 passes	1.99	2.97	4.96
2050	4 passes	2.64	4.81	7.45
2100	8" lifts, 2 passes	1.67	2.08	3.75
2150	4 passes	1.99	2.97	4.96
2200	200 HP dozer & roller compactors, 150' haul, 4" lifts, 2 passes	1.70	1.55	3.25
2250	4 passes	2.31	2.60	4.91
2300	8" lifts, 2 passes	1.40	1.03	2.43
2350	4 passes	1.70	1.55	3.25
2600	300' haul, 4" lifts, 2 passes	2.11	1.74	3.85
2650	4 passes	2.72	2.79	5.51
2700	8" lifts, 2 passes	1.81	1.22	3.03
2750	4 passes	2.11	1.74	3.85

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-52

ICF KAISER ENGINEERS

JOB No. 04302 40300

SHEET 1 OF 1

Alternative D: Windrow Composting

Landfill / Liner System

DESIGNED BY RRL DATE 9/1/9

CHECKED BY RDB DATE 9/ /9-

22,200 yd^3 of Soil will be treated by windrow Composting. The final Volume will be 39,000 yd^3. Landfill depth will be 10' with a 3' clay liner for a total of 13'.

Landfill Surface area = 108,000 ft^2 ~ 2.5 acres

Landfill Size = 328' x 328' x 13'

Clay for Liner to be taken from on-site Borrow Area

$$\text{Volume} = \underbrace{(108{,}000\ ft^2)(3ft)\left(\frac{1\,yd^3}{27\,ft^3}\right)}_{\text{Base}} + \underbrace{4(3ft \times 13ft \times 328ft)\left(\frac{1\,yd^3}{27\,ft^3}\right)}_{\text{walls}}$$

$\sim 14{,}000\ yd^3$

1) <u>Clay Excavation for Liner</u>

½ yd^3 backhoe and 2-12 yd^3 dumptrucks, 4 mile round trip

Unit Cost = \$7.93/yd^3

Cost = (14,000 yd^3)(\$7.93/yd^3) = \$111,120 ~ \$112,000

2) <u>Clay Backfill and Compaction</u>

Clay will be backfilled w/ a 200hp Bulldozer in 4" lifts.
Clay will be compacted with Sheepsfoot compactor

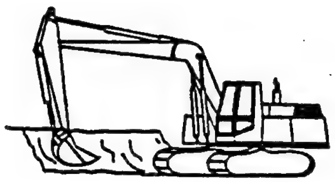
Unit Cost = \$2.51/yd^3

Cost = (14,000/yd^3)(\$2.51/yd^3) ≈ \$35,000

Total Cost = \$112,000 + \$35,000 = $\boxed{\$147{,}000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Excavate Clay



The Excavation of Clay System balances the productivity of excavating equipment to hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 40%.

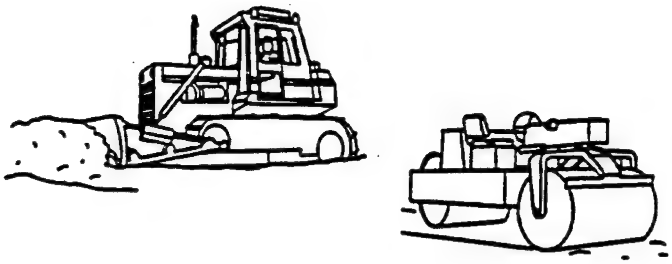
The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 1-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-416-1000					
EXCAVATE CLAY, 1/2 $FF3CY BACKHOE, TWO 6 CY DUMP TRUCKS,2 MI ROUND TRIP					
Excavating bulk hyd. backhoe, wheel mtd. 1/2 C.Y.	1.000	C.Y.	1.31	2.12	3.43
Haul earth, 6 C.Y. dump truck, 2 mile round trip, 2.6 loads/hr	1.000	C.Y.	4	2.72	6.72
Spotter at earth fill dump or in cut	.020	Hr.		.69	.69
Total			5.31	5.53	10.84

12.1-416	Excavate Clay	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Excavate clay, 1/2C.Y. backhoe, two 6C.Y. dump trucks, 2mile round trip	5.30	5.55	10.85
1200	Three 6 C.Y. dump trucks, 4 mile round trip	7.15	6.70	13.85
1400	Two 12 C.Y. dump trucks, 4 mile round trip	5.15	4.54	9.69
1600	3/4 C.Y. backhoe, three 6 C.Y. dump trucks, 2 mile round trip	5.20	4.58	9.78
1700	Five 6 C.Y. dump trucks, 4 mile round trip	6.90	5.60	12.50
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.98	3.26	7.24
1900	Three 12 C.Y. dump trucks, 4 mile round trip	5.05	3.77	8.82
2000	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.80	4.20	10
2100	Three 12 C.Y. dump trucks, 1 mile round trip	3.18	2.12	5.30
2200	Six 12 C.Y. dump trucks, 4 mile round trip	4.78	3.15	7.93
2300	Three 16 C.Y. dump trailers, 2 mile round trip	3.52	2.01	5.53
2400	Four 16 C.Y. dump trailers, 4 mile round trip	4.38	2.40	6.78
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.69	1.66	4.35
2800	2-1/2 C.Y. backhoe, eight 12 C.Y. dump trucks, 3 mile round trip	3.99	2.44	6.43
2900	Four 16 C.Y. dump trailers, 1 mile round trip	2.84	1.44	4.28
3000	Six 16 C.Y. dump trailers, 3 mile round trip	3.81	2	5.81
3100	Four 20 C.Y. dump trailers, 2 mile round trip	2.96	1.62	4.58
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.76	1.97	5.73
3400	3-1/2 C.Y. backhoe, ten 12 C.Y. dump trucks, 2 mile round trip	4.06	2.05	6.11
3500	Six 16 C.Y. dump trailers, 1 mile round trip	3.40	1.43	4.83
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.76	2.05	6.81
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.93	1.68	5.61
4000	1/2 C.Y. pwr. shovel, three 6 C.Y. dump trucks, 1 mile round trip	2.87	2.61	5.48
4100	Six 6 C.Y. dump trucks, 4 mile round trip	6.65	5.50	12.15
4200	Two 12 C.Y. dump trucks, 1 mile round trip	3.12	2.47	5.59
4400	Three 12 C.Y. dump trucks, 3 mile round trip	4.13	2.98	7.11
4600	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.64	3.79	8.43
4700	Nine 6 C.Y. dump trucks, 4 mile round trip	6.50	5	11.50
4800	Three 12 C.Y. dump trucks, 1 mile round trip	2.99	2.11	5.10
4900	Four 12 C.Y. dump trucks, 3 mile round trip	4.08	2.77	6.85
5000	Two 16 C.Y. dump trailers, 1 mile round trip	2.94	1.91	4.85
5200	Three 16 C.Y. dump trailers, 3 mile round trip	3.91	2.33	6.24
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 2 mile round trip	3.52	2.24	5.76
5500	Four 16 C.Y. dump trailers, 1 mile round trip	2.78	1.43	4.21

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-54



The Clay Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Clay Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
SYSTEM 12.1-726-1000					
CLAY BACKFILL, 75 HP DOZER & TAMPER, 50' HAUL, 6"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, clay from stockpile	1.000	C.Y.	.35	.49	.84
Water wagon rent per day	.004	Hr.	.27	.12	.39
Compaction, tamper, 4" lifts, 2 passes	1.000	C.Y.	.16	.62	.78
Total			.78	1.23	2.01

12.1-726	Clay Backfill	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
1000	Clay backfill, 75 HP dozer & tamper compactors, 50'haul,4"lifts, 2 passes	.78	1.23	2.01
1050	4 passes	.95	1.84	2.79
1100	8" lifts, 2 passes	.70	.92	1.62
1150	4 passes	.78	1.23	2.01
1200	150' haul, 4" lifts, 2 passes	1.13	1.73	2.86
1250	4 passes	1.30	2.34	3.64
1300	8" lifts, 2 passes	1.05	1.42	2.47
1350	4 passes	1.13	1.73	2.86
1400	300' haul, 4" lifts, 2 passes	1.46	2.19	3.65
1450	4 passes	1.63	2.80	4.43
1500	8" lifts, passes	1.38	1.88	3.26
1550	Passes	1.46	2.19	3.65
1600	105 HP dozer & tamper compactors, 50' haul, 4" lifts, 2 passes	.83	1.12	1.95
1650	4 passes	1	1.73	2.73
1700	8" lifts, 2 passes	.75	.81	1.56
1750	4 passes	.83	1.12	1.95
1800	150' haul, 4" lifts, 2 passes	1.24	1.50	2.74
1850	4 passes	1.41	2.11	3.52
1900	8" lifts, 2 passes	1.16	1.19	2.35
1950	4 passes	1.24	1.50	2.74
2000	300' haul, 4" lifts, 2 passes	1.63	1.87	3.50
2050	4 passes	1.80	2.48	4.28
2100	8" lifts, 2 passes	1.55	1.56	3.11
2150	4 passes	1.63	1.87	3.50
2200	200 HP dozer & sheepsfoot compactors, 150' haul, 5" lifts, 2 passes	1.41	.71	2.12
2250	4 passes	1.64	.87	2.51
2300	8" lifts, 2 passes	1.30	.63	1.93
2350	4 passes	1.41	.71	2.12
2600	300' haul, 4" lifts, 2 passes	1.86	.92	2.78
2650	4 passes	2.09	1.08	3.17
2700	8" lifts, 2 passes	1.75	.84	2.59
2750	4 passes	1.86	.92	2.78

B-55

ICF KAISER ENGINEERS	JOB NO. 04302407?00 SHEET 1 OF 2
Alternative D: Windrow Composting	DESIGNED BY RRL DATE 9/1/?
Landfill Cap	CHECKED BY DATE

Construction of the landfill cap will consist of a 30-inch layer of compacted clay covered with an 8-inch layer of topsoil. Once constructed, the cap will be revegetated. Costs include one upgradient and two downgradient monitoring wells. Area = 3 acres to allow excess coverage over landfill.

1) Clay Layer

$$\text{Volume} = (3\text{acres})\left(\frac{43560\,ft^2}{acre}\right)\left(\frac{30''}{12''}\right)\left(\frac{1\,yd^3}{27\,ft^3}\right) = 12{,}100\ yd^3$$

Unit Cost: Excavate and Haul = \$7.93/yd³
Backfill and Compact = \$2.51/yd³
\$10.44/yd³

$$\text{Cost} = (12{,}100\,yd^3)(\$10.44/yd^3) = \$126{,}324 \sim \$127{,}000$$

2) Topsoil Layer

$$\text{Volume} = (3\text{acres})\left(\frac{43560\,ft^2}{acre}\right)\left(\frac{8}{12}\right)\left(\frac{1\,yd^3}{27\,ft^3}\right) \approx 3{,}300\ yd^3$$

Unit Cost: Excavate and Haul = \$7.08/yd³
Backfill = \$1.20/yd³
\$8.28/yd³

$$\text{Cost} = (3{,}300\,yd^3)(\$8.28/yd^3) = \$27{,}324 \sim \$28{,}000$$

3) Revegetate

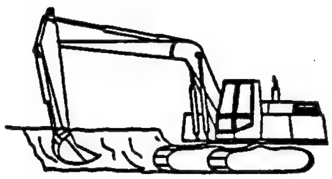
Revegetation will include hydroseeding with mulch and fertilizer.

Unit Cost = \$39/1000 ft²

$$\text{Cost} = (3\,ac)\left(\frac{43{,}560\,ft^2}{acre}\right)(\$39/1000\,ft^2) = \$5096 \sim \$6{,}000$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Excavate Clay



The Excavation of Clay System balances the productivity of excavating equipment to hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 40%.

The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 1-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

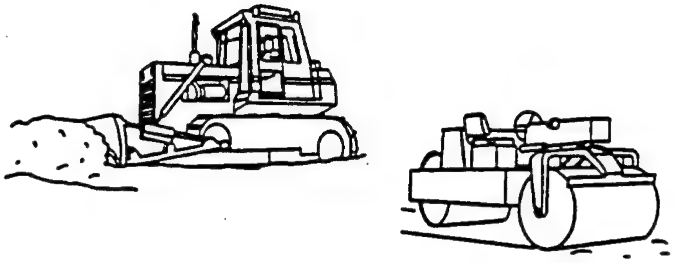
System Components	QUANTITY	UNIT	COST PER C.Y.		
			EQUIP.	LABOR	TOTAL
SYSTEM 12.1-416-1000					
EXCAVATE CLAY, 1/2 $FF3CY BACKHOE, TWO 6 CY DUMP TRUCKS,2 MI ROUND TRIP					
Excavating bulk hyd. backhoe, wheel mtd. 1/2 C.Y.	1.000	C.Y.	1.31	2.12	3.43
Haul earth, 6 C.Y. dump truck, 2 mile round trip, 2.6 loads/hr	1.000	C.Y.	4	2.72	6.72
Spotter at earth fill dump or in cut	.020	Hr.		.69	.69
Total			5.31	5.53	10.84

12.1-416	Excavate Clay	COST PER C.Y.		
		EQUIP.	LABOR	TOTAL
1000	Excavate clay, 1/2C.Y. backhoe, two 6C.Y. dump trucks, 2mile round trip	5.30	5.55	10.85
1200	Three 6 C.Y. dump trucks, 4 mile round trip	7.15	6.70	13.85
1400	Two 12 C.Y. dump trucks, 4 mile round trip	5.15	4.54	9.69
1600	3/4 C.Y. backhoe, three 6 C.Y. dump trucks, 2 mile round trip	5.20	4.58	9.78
1700	Five 6 C.Y. dump trucks, 4 mile round trip	6.90	5.60	12.50
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.98	3.26	7.24
1900	Three 12 C.Y. dump trucks, 4 mile round trip	5.05	3.77	8.82
2000	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.80	4.20	10
2100	Three 12 C.Y. dump trucks, 1 mile round trip	3.18	2.12	5.30
2200	Six 12 C.Y. dump trucks, 4 mile round trip	4.78	3.15	7.93
2300	Three 16 C.Y. dump trailers, 2 mile round trip	3.52	2.01	5.53
2400	Four 16 C.Y. dump trailers, 4 mile round trip	4.38	2.40	6.78
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.69	1.66	4.35
2800	2-1/2 C.Y. backhoe, eight 12 C.Y. dump trucks, 3 mile round trip	3.99	2.44	6.43
2900	Four 16 C.Y. dump trailers, 1 mile round trip	2.84	1.44	4.28
3000	Six 16 C.Y. dump trailers, 3 mile round trip	3.81	2	5.81
3100	Four 20 C.Y. dump trailers, 2 mile round trip	2.96	1.62	4.58
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.76	1.97	5.73
3400	3-1/2 C.Y. backhoe, ten 12 C.Y. dump trucks, 2 mile round trip	4.06	2.05	6.11
3500	Six 16 C.Y. dump trailers, 1 mile round trip	3.40	1.43	4.83
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.76	2.05	6.81
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.93	1.68	5.61
4000	1/2 C.Y. pwr. shovel, three 6 C.Y. dump trucks, 1 mile round trip	2.87	2.61	5.48
4100	Six 6 C.Y. dump trucks, 4 mile round trip	6.65	5.50	12.15
4200	Two 12 C.Y. dump trucks, 1 mile round trip	3.12	2.47	5.59
4400	Three 12 C.Y. dump trucks, 3 mile round trip	4.13	2.98	7.11
4600	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.64	3.79	8.43
4700	Nine 6 C.Y. dump trucks, 4 mile round trip	6.50	5	11.50
4800	Three 12 C.Y. dump trucks, 1 mile round trip	2.99	2.11	5.10
4900	Four 12 C.Y. dump trucks, 3 mile round trip	4.08	2.77	6.85
5000	Two 16 C.Y. dump trailers, 1 mile round trip	2.94	1.91	4.85
5200	Three 16 C.Y. dump trailers, 3 mile round trip	3.91	2.33	6.24
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 2 mile round trip	3.52	2.24	5.76
5500	Four 16 C.Y. dump trailers, 1 mile round trip	2.78	1.43	4.21

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-57

Clay Backfill



The Clay Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

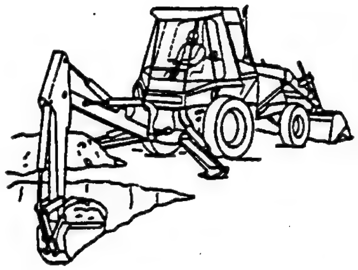
The Expanded System Listing shows Clay Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-726-1000					
CLAY BACKFILL, 75 HP DOZER & TAMPER, 50' HAUL, 6"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, clay from stockpile	1.000	C.Y.	.35	.49	.84
Water wagon rent per day	.004	Hr.	.27	.12	.39
Compaction, tamper, 4" lifts, 2 passes	1.000	C.Y.	.16	.62	.78
Total			.78	1.23	2.01

12.1-726	Clay Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Clay backfill, 75 HP dozer & tamper compactors, 50'haul,4"lifts, 2 passes	.78	1.23	2.01
1050	4 passes	.95	1.84	2.79
1100	8" lifts, 2 passes	.70	.92	1.62
1150	4 passes	.78	1.23	2.01
1200	150' haul, 4" lifts, 2 passes	1.13	1.73	2.86
1250	4 passes	1.30	2.34	3.64
1300	8" lifts, 2 passes	1.05	1.42	2.47
1350	4 passes	1.13	1.73	2.86
1400	300' haul, 4" lifts, 2 passes	1.46	2.19	3.65
1450	4 passes	1.63	2.80	4.43
1500	8" lifts, passes	1.38	1.88	3.26
1550	Passes	1.46	2.19	3.65
1600	105 HP dozer & tamper compactors, 50' haul, 4" lifts, 2 passes	.83	1.12	1.95
1650	4 passes	1	1.73	2.73
1700	8" lifts, 2 passes	.75	.81	1.56
1750	4 passes	.83	1.12	1.95
1800	150' haul, 4" lifts, 2 passes	1.24	1.50	2.74
1850	4 passes	1.41	2.11	3.52
1900	8" lifts, 2 passes	1.16	1.19	2.35
1950	4 passes	1.24	1.50	2.74
2000	300' haul, 4" lifts, 2 passes	1.63	1.87	3.50
2050	4 passes	1.80	2.48	4.28
2100	8" lifts, 2 passes	1.55	1.56	3.11
2150	4 passes	1.63	1.87	3.50
2200	200 HP dozer & sheepsfoot compactors, 150' haul, 5" lifts, 2 passes	1.41	.71	2.12
2250	4 passes	1.64	.87	2.51
2300	8" lifts, 2 passes	1.30	.63	1.93
2350	4 passes	1.41	.71	2.12
2600	300' haul, 4" lifts, 2 passes	1.86	.92	2.78
2650	4 passes	2.09	1.08	3.17
2700	8" lifts, 2 passes	1.75	.84	2.59
2750	4 passes	1.86	.92	2.78

13-58

See the Reference Section for reference number information, Crew Listings and City Cost Indexes



The Excavation of Common Earth System balances the productivity of the excavating equipment to the hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 25% for hauling.

The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 3-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Dragline bucket rigs range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
SYSTEM 12.1-414-1000					
EXCAVATE COMMON EARTH, 1/2 $FF3 CY BACKHOE, TWO 6 CY DUMP TRUCKS, 1 MRT					
Excavating, bulk hyd. backhoe wheel mtd., 1/2 C.Y.	1.000	C.Y.	.92	1.49	2.41
Haul earth, 6 C.Y. dump truck, 1 mile round trip, 3.3 loads/hr	1.000	C.Y.	1.86	1.26	3.12
Spotter at earth fill dump or in cut	.020	Hr.		.48	.48
Total			2.78	3.23	6.01

12.1-414	Excavate Common Earth	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
1000	Excavate common earth, 1/2 C.Y. backhoe,two 6 C.Y. dump trucks, 1MRT	2.78	3.23	6.01
1200	Three 6 C.Y. dump trucks, 3 mile round trip	5.45	5.10	10.55
1400	Two 12 C.Y. dump trucks, 4 mile round trip	4.60	4.05	8.65
1600	3/4 C.Y. backhoe, three C.Y. dump trucks, 1 mile round trip	2.69	2.58	5.27
1700	Five 6 C.Y. dump trucks, 3 mile round trip	5.25	4.58	9.83
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.55	2.93	6.48
1900	Two 16 C.Y. dump trailers, 3 mile round trip	3.61	2.41	6.02
2000	Two 20 C.Y. dump trailers, 4 mile round trip	3.67	2.54	6.21
2200	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.15	3.92	9.07
2300	Four 12 C.Y. dump trucks, 2 mile round trip	3.27	2.31	5.58
2400	Six 12 C.Y. dump trucks, 4 mile round trip	4.26	2.82	7.08
2500	Three 16 C.Y. dump trailers, 2 mile round trip	3.14	1.79	4.93
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.41	1.47	3.88
2700	Three 20 C.Y. dump trailer, 3 mile round trip	3.22	1.83	5.05
2800	2-1/2 C.Y. backhoe, six 12 C.Y. dump trucks, 1 mile round trip	2.59	1.60	4.19
2900	Eight 12 C.Y. dump trucks, 3 mile round trip	3.56	2.18	5.74
3000	Four 16 C.Y. dump trailers, 1 mile round trip	2.54	1.30	3.84
3100	Six 16 C.Y. dump trailers, 3 mile round trip	3.41	1.78	5.19
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.36	1.75	5.11
3400	3-1/2 C.Y. backhoe, six 16 C.Y. dump trailers, 1 mile round trip	3.03	1.29	4.32
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.25	1.85	6.10
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.51	1.52	5.03
4000	1/2 C.Y. pwr. shovel, four 6 C.Y. dump trucks, 2 mile round trip	4.27	3.50	7.77
4100	Two 12 C.Y. dump trucks, 1 mile round trip	2.77	2.21	4.98
4200	Four 12 C.Y. dump trucks, 4 mile round trip	4.21	2.90	7.11
4300	Two 16 C.Y. dump trailers, 2 mile round trip	3.09	2.07	5.16
4400	Two 20 C.Y. dump trailers, 4 mile round trip	3.57	2.41	5.98
4500				
4800	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.15	3.37	7.52
4900	Three 12 C.Y. dump trucks, 1 mile round trip	2.66	1.88	4.54
5000	Five 12 C.Y. dump trucks, 4 mile round trip	4.21	2.78	6.99
5100	Three 16 C.Y. dump trailers, 3 mile round trip	3.49	2.08	5.57
5200	Three 20 C.Y. dump trailers, 4 mile round trip	3.44	2.05	5.49
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 1 mile round trip	2.54	1.59	4.13

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-59

		022 100 | Grading	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
104	0010	GRADING Site excav. & fill, see div 022-200									
	0020	Fine grading, see div 025-122									
		022 200 | Excav./Backfill/Compact.									
204	0010	BACKFILL By hand, no compaction, light soil R022-220	1 Clab	14	.571	C.Y.		10.85		10.85	17.20
	0100	Heavy soil		11	.727			13.80		13.80	22
	0300	Compaction in 6" layers, hand tamp, add to above		20.60	.388			7.40		7.40	11.70
	0400	Roller compaction operator walking, add	B-10A	100	.120			2.71	.82	3.53	5.10
	0500	Air tamp, add	B-9	190	.211			4.08	.78	4.86	7.30
	0600	Vibrating plate, add	A-1	60	.133			2.53	.97	3.50	5.10
	0800	Compaction in 12" layers, hand tamp, add to above	1 Clab	34	.235			4.47		4.47	7.10
	0900	Roller compaction operator walking, add	B-10A	150	.080			1.81	.54	2.35	3.39
	1000	Air tamp, add	B-9	285	.140			2.72	.52	3.24	4.88
	1100	Vibrating plate, add	A-1	90	.089			1.69	.65	2.34	3.39
208	0010	BACKFILL, STRUCTURAL Dozer or F.E. loader									
	0020	From existing stockpile, no compaction									
	2000	75 H.P., 50' haul, sand & gravel	B-10L	1,100	.011	C.Y.		.25	.25	.50	.65
	2020	Common earth		975	.012			.28	.28	.56	.74
	2040	Clay		850	.014			.32	.32	.64	.84
	2200	150' haul, sand & gravel		550	.022			.49	.49	.98	1.30
	2220	Common earth		490	.024			.55	.55	1.10	1.47
	2240	Clay		425	.028			.64	.64	1.28	1.69
	2400	300' haul, sand & gravel		370	.032			.73	.73	1.46	1.94
	2420	Common earth		330	.036			.82	.82	1.64	2.18
	2440	Clay		290	.041			.93	.94	1.87	2.48
	3000	105 H.P., 50' haul, sand & gravel	B-10W	1,350	.009			.20	.30	.50	.64
	3020	Common earth		1,225	.010			.22	.33	.55	.70
	3040	Clay		1,100	.011			.25	.37	.62	.78
	3200	150' haul, sand & gravel		670	.018			.40	.60	1	1.29
	3220	Common earth		610	.020			.44	.66	1.10	1.42
	3240	Clay		550	.022			.49	.73	1.22	1.57
	3300	300' haul, sand & gravel		465	.026			.58	.87	1.45	1.85
	3320	Common earth		415	.029			.65	.97	1.62	2.08
	3340	Clay		370	.032			.73	1.09	1.82	2.33
	4000	200 H.P., 50' haul, sand & gravel	B-10B	2,500	.005			.11	.33	.44	.53
	4020	Common earth		2,200	.005			.12	.37	.49	.60
	4040	Clay		1,950	.006			.14	.42	.56	.67
	4200	150' haul, sand & gravel		1,225	.010			.22	.67	.89	1.08
	4220	Common earth		1,100	.011			.25	.75	1	1.20
	4240	Clay		975	.012			.28	.84	1.12	1.35
	4400	300' haul, sand & gravel		805	.015			.34	1.02	1.36	1.64
	4420	Common earth		735	.016			.37	1.12	1.49	1.80
	4440	Clay		660	.018			.41	1.24	1.65	2.01
	5000	300 H.P., 50' haul, sand & gravel	B-10M	3,170	.004			.09	.31	.40	.48
	5020	Common earth		2,900	.004			.09	.34	.43	.52
	5040	Clay		2,700	.004			.10	.37	.47	.57
	5200	150' haul, sand & gravel		2,200	.005			.12	.45	.57	.69
	5220	Common earth		1,950	.006			.14	.51	.65	.77
	5240	Clay		1,700	.007			.16	.59	.75	.89
	5400	300' haul, sand & gravel		1,500	.008			.18	.66	.84	1.01
	5420	Common earth		1,350	.009			.20	.74	.94	1.12
	5440	Clay		1,225	.010			.22	.81	1.03	1.23
	6000	For compaction, see div. 022-226									
	6010	For trench backfill, see div. 022-254 & 258									
216	0011	BORROW Bank measure, loaded onto 12 C.Y. hauler, no haul incl.									
	4000	Common earth, shovel, 1 C.Y. bucket	B-12N	840	.019	C.Y.	3.58	.44	.72	4.74	5.40

B-60

029 200 | Soil Preparation

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
204	6000	Tilling topsoil, 20 HP tractor, disk harrow, 2" deep	B-66	50,000	.001	S.Y.					.01	204
	6050	4" deep		40,000	.001						.02	
	6100	6" deep		30,000	.001			.01	.01	.02	.02	
	6150	26" rototiller, 2" deep	A-1	1,250	.006			.12	.05	.17	.25	
	6200	4" deep		1,000	.008			.15	.06	.21	.32	
	6250	6" deep		750	.011			.20	.08	.28	.43	
	7000	Lawn maintenance see Division 029-700										
208	0010	PLANT BED PREPARATION										208
	0100	Backfill planting pit, by hand, on site topsoil	2 Clab	18	.889	C.Y.		16.90		16.90	28.50	
	0200	Prepared planting mix	•	24	.667			12.65		12.65	21.50	
	0300	Skid steer loader, on site topsoil	B-62	340	.071			1.44	.28	1.72	2.70	
	0400	Prepared planting mix	•	410	.059			1.20	.23	1.43	2.24	
	1000	Excavate planting pit, by hand, sandy soil	2 Clab	16	1			19		19	32	
	1100	Heavy soil or clay	•	8	2			38		38	64	
	1200	1/2 C.Y. backhoe, sandy soil	B-11C	150	.107			2.31	1.33	3.64	5.25	
	1300	Heavy soil or clay	•	115	.139			3.02	1.74	4.76	5.85	
	2000	Mix planting soil, incl. loam, manure, peat, by hand	2 Clab	60	.267		24	5.05		29.05	35	
	2100	Skid steer loader	B-62	150	.160		24	3.28	.64	27.92	32.50	
	3000	Pile sod, skid steer loader	•	2,500	.009	S.Y.		.18	.03	.21	.33	
	3100	By hand	2 Clab	400	.040			.76		.76	1.28	
	4000	Remove sod, F.E. loader	B-10S	2,000	.006			.14	.16	.30	.39	
	4100	Sod cutter	B-12K	3,200	.005			.12	.26	.38	.48	
	4200	By hand	2 Clab	240	.067			1.27		1.27	2.13	

029 300 | Lawns & Grasses

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
308	0010	SEEDING Athletic field mix, 8#/M.S.F., push spreader (R029-310)	A-1	10	.800	M.S.F.	11.80	15.20	5.85	32.85	45	308
	0100	Tractor spreader	B-66	52	.154		11.80	3.60	3.51	18.91	22.50	
	0200	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	0400	Birdsfoot trefoil, .45#/M.S.F., push spreader	A-1	10	.800		13.95	15.20	5.85	35	47.50	
	0500	Tractor spreader	B-66	52	.154		13.95	3.60	3.51	21.06	25	
	0600	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		28.50	6.30	6.90	41.70	49.50	
	0800	Bluegrass, 4#/M.S.F., common, push spreader	A-1	10	.800		5.05	15.20	5.85	26.10	37.50	
	0900	Tractor spreader	B-66	52	.154		5.05	3.60	3.51	12.16	15.20	
	1000	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		19.15	6.30	6.90	32.35	39	
	1100	Baron, push spreader	A-1	10	.800		10.60	15.20	5.85	31.65	43.50	
	1200	Tractor spreader	B-66	52	.154		10.60	3.60	3.51	17.71	21.50	
	1300	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	1500	Clover, 0.67#/M.S.F., white, push spreader	A-1	10	.800		2.50	15.20	5.85	23.55	34.50	
	1600	Tractor spreader	B-66	52	.154		2.50	3.60	3.51	9.61	12.40	
	1700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		16.65	6.30	6.90	29.85	36.50	
	1800	Ladino, push spreader	A-1	10	.800		4.23	15.20	5.85	25.28	36.50	
	1900	Tractor spreader	B-66	52	.154		4.23	3.60	3.51	11.34	14.30	
	2000	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		18.20	6.30	6.90	31.40	38	
	2200	Fescue 5.5#/M.S.F., tall, push spreader	A-1	10	.800		7.35	15.20	5.85	28.40	40	
	2300	Tractor spreader	B-66	52	.154		7.35	3.60	3.51	14.46	17.70	
	2400	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		22.50	6.30	6.90	35.70	42.50	
	2500	Chewing, push spreader	A-1	10	.800		8.55	15.20	5.85	29.60	41.50	
	2600	Tractor spreader	B-66	52	.154		8.55	3.60	3.51	15.66	19.05	
	2700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		23.50	6.30	6.90	36.70	43.50	
	2900	Crown vetch, 4#/M.S.F., push spreader	A-1	10	.800		38.50	15.20	5.85	59.55	74.50	
	3000	Tractor spreader	B-66	52	.154		38.50	3.60	3.51	45.61	52	
	3100	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		53	6.30	6.90	66.20	76	
	3300	Rye, 10#/M.S.F., annual, push spreader	A-1	10	.800		4.83	15.20	5.85	25.88	37	
	3400	Tractor spreader	B-66	52	.154		4.83	3.60	3.51	11.94	14.95	
	3500	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		18.25	6.30	6.90	31.45	38	

B-61

ICF KAISER ENGINEERS

Job No. C430240300

Alternative D: Windrow Composting

Landfill Cap

DESIGNED BY RRL DATE 9/1/

CHECKED BY TDW DATE

4) Erosion Control

Used to prevent wind blown emission and surface runoff of soil

Silt Fence - Assume perimeter ~ 1600 ft

Unit Cost = \$0.72/ft

Cost = (1600 ft)(\$0.72/ft) = \$1,200

Polyethylene Sheeting - To cover 10% of Cap Area

Area = (3 acres)(10%) = 0.3 acres

Unit Cost = \$0.34/yd² - 4 mil Polyethylene Sheeting

$\text{Cost} = (0.3\,ac)\left(\frac{43560\,ft^2}{ac}\right)\left(\frac{yd^2}{9\,ft^2}\right)\left(\frac{\$0.34}{yd^2}\right) = \$493 \sim \$500$

Total Cost = \$127,000 + \$28,000 + \$6,000 + \$1,200 + \$500 = \$162,700 ~ \$163,000

$\boxed{\text{Total Cost} = \$163,000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

022 400 | Soil Stabilization

Ref	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
412	1030	8" deep	B-74	1,050	.061	S.Y.	1.05	1.35	2.86	5.26	6.40
	1060	12" deep		960	.067		1.57	1.47	3.13	6.17	7.45
	1100	6% mix, 6" deep		1,100	.058		1.15	1.29	2.73	5.17	6.25
	1120	8" deep		1,050	.061		1.50	1.35	2.86	5.71	6.90
	1160	12" deep		960	.067		2.27	1.47	3.13	6.87	8.20
	1200	9% mix, 6" deep		1,100	.058		1.74	1.29	2.73	5.76	6.90
	1220	8" deep		1,050	.061		2.27	1.35	2.86	6.48	7.75
	1260	12" deep		960	.067		3.42	1.47	3.13	8.02	9.50
	1300	12% mix, 6" deep		1,100	.058		2.27	1.29	2.73	6.29	7.50
	1320	8" deep		1,050	.061		3.04	1.35	2.86	7.25	8.55
	1360	12" deep		960	.067		4.54	1.47	3.13	9.14	10.70
	2020	Hydrated lime, for base, 2% mix by weight, 6" deep		1,800	.036		.92	.79	1.67	3.38	4.07
	2030	8" deep		1,700	.038		1.21	.83	1.77	3.81	4.56
	2060	12" deep		1,550	.041		1.76	.91	1.94	4.61	5.45
	2100	4% mix, 6" deep		1,800	.036		1.78	.79	1.67	4.24	5
	2120	8" deep		1,700	.038		2.41	.83	1.77	5.01	5.90
	2160	12" deep		1,550	.041		3.61	.91	1.94	6.46	7.50
	2200	6% mix, 6" deep		1,800	.036		2.70	.79	1.67	5.16	6.05
	2220	8" deep		1,700	.038		3.61	.83	1.77	6.21	7.20
	2260	12" deep		1,550	.041		5.35	.91	1.94	8.20	9.45

022 500 | Vibroflotation

Ref	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P
504	0010	VIBROFLOTATION									
	0900	Vibroflotation compacted sand cylinder, minimum	B-60	750	.075	V.L.F.		1.62	1.28	2.90	3.92
	0950	Maximum		325	.172			3.74	2.95	6.69	9.05
	1100	Vibro replacement compacted stone cylinder, minimum		500	.112			2.43	1.92	4.35	5.90
	1150	Maximum		250	.224			4.86	3.83	8.69	11.75
	1300	Mobilization and demobilization, minimum		.47	119	Total		2,575	2,025	4,600	6,275
	1400	Maximum		.14	400	"		8,675	6,850	15,525	21,000

022 700 | Slope/Erosion Control

Ref	Line	Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P
702	0010	CUT DRAINAGE DITCH Common earth	B-11L	6,000	.003	L.F.		.06	.09	.15	.18
	0200	Clay and till		4,200	.004			.08	.12	.20	.27
	0250	Clean wet drainage ditch		10,000	.002			.03	.05	.08	.11
704	0010	EROSION CONTROL Jute mesh, 100 S.Y. per roll, 4' wide, stapled	B-1	2,500	.010	S.Y.	.62	.19		.81	.98
	0060	Nylon, 3 dimensional		2,500	.010		3.50	.19		3.69	4.15
	0070	Paper biodegradable mesh		2,500	.010		.04	.19		.23	.34
	0080	Paper mulch	B-64	20,000	.001		.02	.02	.01	.05	.05
	0100	Plastic netting, stapled, 2" x 1" mesh, 20 mil	B-1	2,500	.010		.33	.19		.52	.66
	0200	Polypropylene mesh, stapled, 6.5 oz./S.Y.		2,500	.010		1.63	.19		1.82	2.09
	0300	Tobacco netting, or jute mesh #2, stapled		2,500	.010		.04	.19		.23	.34
	1000	Silt fence, polypropylene, ideal conditions	2 Clab	1,600	.010	L.F.	.38	.19		.57	.72
	1100	Adverse conditions	"	950	.017	"	.38	.32		.70	.93
	1200	Place and remove hay bales	A-2	3	8	Ton	45	153	52.50	250.50	350
708	0010	RETAINING WALLS Aluminized steel bin, excavation									
	0020	and backfill not included, 10' wide									
	0100	4' high, design A, 5.5' deep	E-2	650	.086	S.F.	13.50	2.22	1.49	17.21	20.50
	0200	8' high, design A, 5.5' deep		615	.091		15.50	2.35	1.58	19.43	23
	0300	10' high, design B, 7.7' deep		580	.097		16.75	2.49	1.67	20.91	24.50
	0400	12' high, design B, 7.7' deep		530	.106		18.10	2.73	1.83	22.66	26.50
	0500	16' high, design B, 7.7' deep		515	.109		19.10	2.81	1.88	23.79	28
	0600	16' high, design C, 9.9' deep		500	.112		20	2.89	1.94	24.83	29
	0700	20' high, design C, 9.9' deep		470	.119		22.50	3.08	2.06	27.64	32.50
	0800	20' high, design D, 12.1' deep		460	.122		23	3.14	2.11	28.25	33.50

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-63

SITE WORK 2

029 300 | Lawns & Grasses

		Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
316	1200	1000 S.F.	B-63	16	2.500	M.S.F.	360	49.50	6	415.50	480	316
	1500	Sloped ground, over 6 M.S.F.		15	2.667		320	53	6.40	379.40	440	
	1600	3 M.S.F.		13.50	2.963		350	59	7.10	416.10	485	
	1700	1000 S.F.		12	3.333		370	66.50	8	444.50	520	
320	0010	STOLENS, SPRIGGING										320
	0100	6" O.C., by hand	1 Clab	4	2	M.S.F.	11.50	38		49.50	72.50	
	0110	Walk behind sprig planter	"	80	.100		11.50	1.90		13.40	15.65	
	0120	Towed sprig planter	B-66	350	.023		11.50	.53	.52	12.55	14.05	
	0130	9" O.C., by hand	1 Clab	5.20	1.538		8.50	29		37.50	56	
	0140	Walk behind sprig planter	"	92	.087		8.50	1.65		10.15	11.95	
	0150	Towed sprig planter	B-66	420	.019		8.50	.45	.43	9.38	10.50	
	0160	12" O.C., by hand	1 Clab	6	1.333		5.25	25.50		30.75	46	
	0170	Walk behind sprig planter	"	110	.073		5.25	1.38		6.63	8	
	0180	Towed sprig planter	B-66	500	.016		5.25	.37	.36	5.98	6.75	
	0200	Broadcast, by hand, 2 Bu per M.S.F.	1 Clab	15	.533		4.65	10.15		14.80	21	
	0210	4 Bu. per M.S.F.		10	.800		9.10	15.20		24.30	34	
	0220	6 Bu. per M.S.F.		6.50	1.231		13.65	23.50		37.15	52	
	0300	Hydro planter, 6 Bu. per M.S.F.	B-64	100	.160		13.65	3.07	2.55	19.27	22.50	
	0320	Manure spreader planting 6 Bu. per M.S.F.	B-66	200	.040		13.65	.94	.91	15.50	17.45	

029 500 | Trees/Plants/Grnd Cover

		Description	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	
516	0010	MULCH										516
	0100	Aged barks, 3" deep, hand spread	1 Clab	100	.080	S.Y.	1.52	1.52		3.04	4.08	
	0150	Skid steer loader	B-63	13.50	2.963	M.S.F.	166	59	7.10	232.10	283	
	0200	Hay, 1" deep, hand spread	1 Clab	475	.017	S.Y.	.16	.32		.48	.69	
	0250	Power mulcher, small	B-64	180	.089	M.S.F.	17.15	1.71	1.41	20.27	23	
	0350	Large	B-65	530	.030	"	17.15	.58	.77	18.50	20.50	
	0370	Fiber mulch recycled newsprint hand spread	1 Clab	500	.016	S.Y.	.07	.30		.37	.56	
	0380	Power mulcher small	B-64	200	.080	M.S.F.	6.75	1.54	1.27	9.56	11.25	
	0390	Power mulcher large	B-65	600	.027	"	6.75	.51	.68	7.94	9	
	0400	Humus peat, 1" deep, hand spread	1 Clab	700	.011	S.Y.	.60	.22		.82	1	
	0450	Push spreader	A-1	2,500	.003	"	.60	.06	.02	.68	.79	
	0550	Tractor spreader	B-66	700	.011	M.S.F.	62.50	.27	.26	63.03	69.50	
	0600	Oat straw, 1" deep, hand spread	1 Clab	475	.017	S.Y.	.22	.32		.54	.75	
	0650	Power mulcher, small	B-64	180	.089	M.S.F.	24	1.71	1.41	27.12	30.50	
	0700	Large	B-65	530	.030	"	24	.58	.77	25.35	28.50	
	0750	Add for asphaltic emulsion	B-45	1,770	.009	Gal.	1.50	.20	.38	2.08	2.38	
	0800	Peat moss, 1" deep, hand spread	1 Clab	900	.009	S.Y.	.84	.17		1.01	1.19	
	0850	Push spreader	A-1	2,500	.003	"	.84	.06	.02	.92	1.05	
	0950	Tractor spreader	B-66	700	.011	M.S.F.	91.50	.27	.26	92.03	102	
	1000	Polyethylene film, 6 mil.	2 Clab	2,000	.008	S.Y.	.15	.15		.30	.41	
	1010	4 mil		2,300	.007		.12	.13		.25	.34	
	1020	1-1/2 mil		2,500	.006		.07	.12		.19	.27	
	1050	Filter fabric weed barrier		2,000	.008		1	.15		1.15	1.34	
	1100	Redwood nuggets, 3" deep, hand spread	1 Clab	150	.053		4.90	1.01		5.91	7	
	1150	Skid steer loader	B-63	13.50	2.963	M.S.F.	545	59	7.10	611.10	700	
	1200	Stone mulch, hand spread, ceramic chips, economy	B-14	125	.384	S.Y.	5.25	7.70	1.60	14.55	19.70	
	1250	Deluxe	"	95	.505	"	7.75	10.15	2.10	20	27	
	1300	Granite chips	B-1	10	2.400	C.Y.	25	47		72	103	
	1400	Marble chips		10	2.400		95	47		142	180	
	1500	Onyx gemstone		10	2.400		280	47		327	385	
	1600	Pea gravel		28	.857		16.20	16.85		33.05	44.50	
	1700	Quartz		10	2.400		120	47		167	207	
	1800	Tar paper, 15 Lb. felt	1 Clab	800	.010	S.Y.	.34	.19		.53	.67	
	1900	Wood chips, 2" deep, hand spread	"	220	.036	"	.85	.69		1.54	2.03	

B-64

ICF KAISER ENGINEERS

JOB No. 04302 40300
SHEET 1 OF 1

Alternative D: Windrow Composting

Treatment Cost

DESIGNED BY RRL DATE 9/1/9
CHECKED BY RDB DATE 9/1/9

$\boxed{\text{Cost} = \$211/\text{ton}}$

Cost Includes:

- Equipment: 1yd³ backhoe, 12yd³ dumptruck, 2yd³ front end loader, windrow turner, sump pump, monitoring equipment
- Site Work: Clearing and Grubbing, Bulk Excavation, Grading, paving, seeding, mulching, and cap for compost backfill
- Buildings: Temporary Structures and Liner System
- Mechanical/Piping: Site Drainage and Storm Runoff Control
- Electrical: Equipment Power Distribution, Site Lighting
- Offsite Analytics

Source: Windrow Composting Engineering/Economic Evaluation (USAEC, 1993c)

CALCULATIONS KE Form No. E-6 Rev. 12-89

ICF KAISER ENGINEERS

Job No. C430240300

Sheet 1 of 2

Alternative D8 Bioslurry

Clean Soil Backfill

DESIGNED BY RRL DATE 9/1/94

CHECKED BY RDP DATE 9/1/94

Disposal Area Size Calculations

Volume of Soil = $(18{,}500\ yd^3)(1.2\ \text{Bulking}) = 22{,}200\ yd^3$

40% Bulking = $(22{,}200\ yd^3)(40\%) = 8{,}800\ yd^3$

10% Daily Cover = $(22{,}200 + 8{,}800)(1.10) \simeq 34{,}000\ yd^3$

$\sim 921{,}000\ ft^3$

Depth = 10 ft

Surface Area = $92{,}000\ ft^2$ or $303\ ft \times 303\ ft$

Add 3 ft of Edges for Liner

Total Volume = $306 \times 306 \times 13 = 1{,}217{,}000\ ft^3 \sim 45{,}000\ yd^3$

Total Surface Area = $306 \times 306 = 93{,}636\ ft^2 \sim 2.2\ ac$

1) Borrow Area Clearing

Clear area to be used as on-site landfill reduce cost by 40% because trees will be burned at OBG, not chipped

Area = 2.2 acres

Unit Cost = $(\$2700/\text{acre})(60\%) = \$1620/\text{acre}$

Hauling to OBG

Hauling will be a 5 mile round trip w/ $12\ yd^3$ dump truck
assume $0.5\ ft^3$ material for every ft^2 cleared

Unit Cost = $(\$6.95/yd^3)(1\ yd^3/27\ ft^3)\left(\frac{.5\ ft^3}{ft^2}\right)\left(\frac{43560\ ft^2}{\text{acre}}\right) = \$5606/\text{acre}$

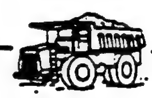
Cost = $(2.2\ \text{acre})(\$1620/ac + \$5606/ac) = \$16{,}000$

		021 100 | Site Clearing	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs				Total Incl O&P	
							Mat.	Labor	Equip.	Total		
04	0010	CLEAR AND GRUB Light, trees to 6" diam., cut & chip	B-7	1	48	Acre		970	1,075	2,045	2,700	104
	0150	Grub stumps and remove	B-30	2	12			255	740	995	1,200	
	0160	Clear & grub brush & stumps	•	.58	41.379			880	2,550	3,430	4,150	
	0200	Medium, trees to 12" diam., cut & chip	B-7	.70	68.571			1,375	1,525	2,900	3,850	
	0250	Grub stumps and remove	B-30	1	24			510	1,475	1,985	2,400	
	0260	Clear & grub dense brush & stumps	•	.47	51.064			1,075	3,150	4,225	5,125	
	0300	Heavy, trees to 24" diam., cut & chip	B-7	.30	160			3,225	3,575	6,800	9,025	
	0350	Grub stumps and remove	B-30	.50	48			1,025	2,950	3,975	4,825	
	0400	If burning is allowed, reduce cut & chip									40%	
	3000	Chipping stumps, to 18" deep, 12" diam.	B-86	20	.400	Ea.		9.75	7.95	17.70	23.50	
	3040	18" diameter		16	.500			12.20	9.95	22.15	29.50	
	3080	24" diameter		14	.571			13.90	11.35	25.25	34	
	3100	30" diameter		12	.667			16.25	13.25	29.50	39.50	
	3120	36" diameter		10	.800			19.50	15.90	35.40	47.50	
	3160	48" diameter		8	1			24.50	19.85	44.35	59.50	
	5000	Tree thinning, feller buncher, conifer										
	5080	Up to 8" diameter	B-93	240	.033	Ea.		.81	1.42	2.23	2.80	
	5120	12" diameter		160	.050			1.22	2.13	3.35	4.21	
	5240	Hardwood, up to 4" diameter		240	.033			.81	1.42	2.23	2.80	
	5280	8" diameter		180	.044			1.08	1.89	2.97	3.74	
	5320	12" diameter		120	.067			1.62	2.84	4.46	5.60	
	7000	Tree removal, congested area, aerial lift truck										
	7040	8" diameter	B-85	7	5.714	Ea.		115	110	225	300	
	7080	12" diameter		6	6.667			135	128	263	350	
	7120	18" diameter		5	8			162	154	316	425	
	7160	24" diameter		4	10			202	193	395	525	
	7240	36" diameter		3	13.333			269	257	526	705	
	7280	48" diameter		2	20			405	385	790	1,050	
108	0010	CLEARING Brush with brush saw	A-1	.25	32	Acre		610	234	844	1,225	108
	0100	By hand	•	.12	66.667			1,275	485	1,760	2,525	
	0300	With dozer, ball and chain, light clearing	B-11A	2	8			173	410	583	720	
	0400	Medium clearing	•	1.50	10.667			231	545	776	960	
	0500	With dozer and brush rake, light	B-11B	1	16			345	1,025	1,370	1,675	
	0550	Medium brush to 4" diameter		.60	26.667			580	1,725	2,305	2,775	
	0600	Heavy brush to 4" diameter		.40	40			865	2,575	3,440	4,175	
	1000	Brush mowing, tractor w/rotary mower, no removal										
	1020	Light density	B-84	2	4	Acre		97.50	104	201.50	264	
	1040	Medium density		1.50	5.333			130	139	269	350	
	1080	Heavy density		1	8			195	209	404	530	
116	0010	FELLING TREES & PILING With tractor, large tract, firm										116
	0020	level terrain, no boulders, less than 12" diam. trees										
	0300	300 HP dozer, up to 400 trees/acre, 0 to 25% hardwoods	B-10M	.75	16	Acre		360	1,325	1,685	2,000	
	0340	25% to 50% hardwoods		.60	20			450	1,650	2,100	2,525	
	0370	75% to 100% hardwoods		.45	26.667			600	2,225	2,825	3,350	
	0400	500 trees/acre, 0% to 25% hardwoods		.60	20			450	1,650	2,100	2,525	
	0440	25% to 50% hardwoods		.48	25			565	2,075	2,640	3,150	
	0470	75% to 100% hardwoods		.36	33.333			750	2,775	3,525	4,225	
	0500	More than 600 trees/acre, 0 to 25% hardwoods		.52	23.077			520	1,925	2,445	2,900	
	0540	25% to 50% hardwoods		.42	28.571			645	2,375	3,020	3,600	
	0570	75% to 100% hardwoods		.31	38.710			875	3,200	4,075	4,875	
	0900	Large tract clearing per tree										
	1500	300 HP dozer, to 12" diameter, softwood	B-10M	320	.038	Ea.		.85	3.11	3.96	4.73	
	1550	Hardwood		100	.120			2.71	9.95	12.66	15.15	
	1600	12" to 24" diameter, softwood		200	.060			1.35	4.98	6.33	7.60	
	1650	Hardwood		80	.150			3.39	12.45	15.84	18.95	

B-67

022 200 | Excav./Backfill/Compact.

	No.	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	1994 Bare Costs Labor	1994 Bare Costs Equip.	1994 Bare Costs Total	Total Incl. O&P	
262	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader										
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14	262
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53	
	0400	For compaction of embankment, see div. 022-226										
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27	
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37	
	0700	9" deep		7,200	.007		.25	.13	.02	.40	.51	
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66	
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22	
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70	
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60	
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85	
	1500	For fill under exterior paving, see division 022-308										
266	0011	HAULING Excavated or borrow material, highway haulers R022-240										
	0012	bank measure, no loading included										266
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50	
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04	
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75	
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80	
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6	
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05	
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91	
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21	
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62	
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25	
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79	
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54	
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95	
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90	
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50	
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31	
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85	
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34	
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75	
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95	
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90	
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95	
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97	
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46	
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92	
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28	
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57	
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80	
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20	
	1300	Hauling in medium traffic, add								20%	20%	
	1400	Heavy traffic, add								30%	30%	
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32	
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30	
	2000	Off highway haulers										
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58	
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72	
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85	
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19	
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48	
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55	



B-68

ICF KAISER ENGINEERS

Job No. 04302 40300

Sheet 2 of 2

Alternative D8 Bioslurry

Clean Soil Backfill

DESIGNED BY	RRL	DATE	9/1/9?
CHECKED BY	RDB	DATE	9/1/94

2) Borrow Area Excavation

Excavation will be performed with a [illegible] yd³ backhoe

Unit Cost = ($1.65/yd³)(1.15 for loading) = $1.90

Cost = (45,000 yd³)($1.90/yd³) = $85,500 ~ $86,000

3) Borrow Material Hauling

Hauling backfill with 12 yd³ dumptruck:

Unit Cost = $6.95/yd³

Cost = (22,200 yd³)($6.95/yd³) = $154,290 ~ $155,000

4) Earth Backfilling

Includes 200 hp Bulldozer, Waterwagon, Compactor Roller

Unit Cost = $3.03/yd³

Cost = (22,200/yd³)($3.03/yd³) = $67,266 ~ $68,000

5) Reseeding

The reseeding will be conducted using hydro or air seeding with mulch and fertilizer

Area = (18,500 yd³)$\left(\frac{27\,ft^3}{yd^3}\right)$(1/10 ft) = 49,950 ft²

Unit Cost = $39/1000 ft²

Cost = (49,950 ft²)($39/1000 ft²) = $1948 ~ $2000

Total Cost = $16,000 + $86,000 + $155,000 + $68,000 + $2,000 = $\boxed{\$327{,}000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

022 200 | Excav./Backfill/Compact.

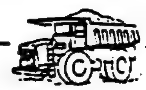
				DAILY	MAN-		1994 BARE COSTS				TOTAL	
			CREW	OUTPUT	HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	INCL O&P	
234	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04	234
	4600	Maximum	•	15,100	.002	•		.04		.04	.07	
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25	
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25	
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14	
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73	
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27	
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4	
	5460	4 mile round trip		200	.040			.79	2.98	3.77	4.49	
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer										
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88	
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20	
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05	
	5820	300' haul		200	.060			1.35	4.98	6.33	7.60	
238	0010	EXCAVATING, BULK BANK MEASURE Common earth piled (R022-240)										238
	0020	For loading onto trucks, add								15%	15%	
	0050	For mobilization and demobilization, see division 022-274 (R022-250)										
	0100	For hauling, see division 022-266										
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.62	.88	1.50	1.91	
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65	
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53	
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77	
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82	
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89	
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr. 	B-12G	160	.100			2.31	2.82	5.13	6.65	
	0550	1 C.Y. cap. = 35 C.Y./hr.	B-12H	280	.057			1.32	1.91	3.23	4.12	
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50	
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1001	3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69	
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71	
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44	
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23	
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23	
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1	
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84	
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20	
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12	
	1601	3 C.Y. cap. = 100 C.Y./hr.	•	1,100	.011			.25	.40	.65	.82	
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96	
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15	
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11	
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44	
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69	
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28	
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18	
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87	
	4000	For soft soil or sand, deduct								15%	15%	
	4100	For heavy soil or stiff clay, add								60%	60%	
	4200	For wet excavation with clamshell or dragline, add								100%	100%	
	4250	All other equipment, add								50%	50%	
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20	
	4450	Maximum	•	60	.267			6.15	8.90	15.05	19.25	
	8000	For hauling excavated material, see div. 022-266										
242	0010	EXCAVATING, BULK, DOZER Open site										242
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56	

SITE WORK 2

B-70

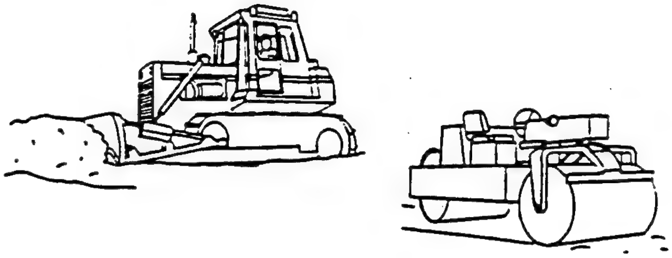
022 | Earthwork

022 200	Excav./Backfill/Compact.	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
252 0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
0400	For compaction of embankment, see div. 022-226									
0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	.27
0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
0700	9" deep		7,200	.007		.25	.13	.02	.40	.51
0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
1500	For fill under exterior paving, see division 022-308									
266 0011	HAULING Excavated or borrow material, highway haulers (R022 -240)									
0012	bank measure, no loading included									
0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.82	5.67	7.05
0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	355	.022			.44	1.12	1.56	1.91
0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
1300	Hauling in medium traffic, add								20%	20%
1400	Heavy traffic, add								30%	30%
1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
2000	Off highway haulers									
2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



B-71

SITE WORK | A12.1-724 | Common Earth Backfill



The Common Earth Backfilling System includes: a bulldozer to place and level backfill in specified lifts: compaction equipment: and a water wagon for adjusting moisture content.

The Expanded System Listing shows Common Earth Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-724-1000					
EARTH BACKFILL, 75 HP DOZER & ROLLER, 50' HAUL, 4"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, common earth, from stockpile	1.000	C.Y.	.31	.43	.74
Water wagon, rent per day	.004	Hr.	.27	.12	.39
Compaction, roller, 4" lifts, 2 passes	.335	Hr.	.65	1.84	2.49
Total			1.23	2.39	3.62

12.1-724	Common Earth Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Earth backfill,75 HP dozer & roller compactors,50' haul,4" lifts,2 passes	1.23	2.39	3.62
1050	4 passes	1.88	4.23	6.11
1100	8" lifts, 2 passes	.91	1.50	2.41
1150	4 passes	1.23	2.39	3.62
1200	150' haul, 4" lifts, 2 passes	1.53	2.82	4.35
1250	4 passes	2.18	4.66	6.84
1300	8" lifts, 2 passes	1.21	1.93	3.14
1350	4 passes	1.53	2.82	4.35
1400	300' haul, 4" lifts, 2 passes	1.83	3.23	5.06
1450	4 passes	2.48	5.05	7.53
1500	8" lifts, 2 passes	1.51	2.34	3.85
1550	4 passes	1.83	3.23	5.06
1600	105 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.28	2.30	3.58
1650	4 passes	1.93	4.14	6.07
1700	8" lifts, 2 passes	.96	1.41	2.37
1750	4 passes	1.28	2.30	3.58
1800	150' haul, 4" lifts, 2 passes	1.65	2.65	4.30
1850	4 passes	2.30	4.49	6.79
1900	8" lifts, 2 passes	1.33	1.76	3.09
1950	4 passes	1.65	2.65	4.30
2000	300' haul, 4" lifts, 2 passes	1.99	2.97	4.96
2050	4 passes	2.64	4.81	7.45
2100	8" lifts, 2 passes	1.67	2.08	3.75
2150	4 passes	1.99	2.97	4.96
2200	200 HP dozer & roller compactors, 150' haul, 4" lifts, 2 passes	1.70	1.55	3.25
2250	4 passes	2.31	2.60	4.91
2300	8" lifts, 2 passes	1.40	1.03	2.43
2350	4 passes	1.70	1.55	3.25
2600	300' haul, 4" lifts, 2 passes	2.11	1.74	3.85
2650	4 passes	2.72	2.79	5.51
2700	8" lifts, 2 passes	1.81	1.22	3.03
2750	4 passes	2.11	1.74	3.85

SITE WORK 12

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

R-72

029 200 | Soil Preparation

		029 200 Soil Preparation	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
204	6000	Tilling topsoil, 20 HP tractor, disk harrow, 2" deep	B-66	50,000	.001	S.Y.					.01	204
	6050	4" deep		40,000	.001						.02	
	6100	6" deep	↓	30,000	.001			.01	.01	.02	.02	
	6150	26" rototiller, 2" deep	A-1	1,250	.006			.12	.05	.17	.25	
	6200	4" deep		1,000	.008			.15	.06	.21	.32	
	6250	6" deep	↓	750	.011	↓		.20	.08	.28	.43	
	7000	Lawn maintenance see Division 029-700										
208	0010	PLANT BED PREPARATION										208
	0100	Backfill planting pit, by hand, on site topsoil	2 Clab	18	.889	C.Y.		16.90		16.90	28.50	
	0200	Prepared planting mix	"	24	.667			12.65		12.65	21.50	
	0300	Skid steer loader, on site topsoil	B-62	340	.071			1.44	.28	1.72	2.70	
	0400	Prepared planting mix	"	410	.059			1.20	.23	1.43	2.24	
	1000	Excavate planting pit, by hand, sandy soil	2 Clab	16	1			19		19	32	
	1100	Heavy soil or clay	"	8	2			38		38	64	
	1200	1/2 C.Y. backhoe, sandy soil	B-11C	150	.107			2.31	1.33	3.64	5.25	
	1300	Heavy soil or clay	"	115	.139			3.02	1.74	4.76	6.85	
	2000	Mix planting soil, incl. loam, manure, peat, by hand	2 Clab	60	.267		24	5.05		29.05	35	
	2100	Skid steer loader	B-62	150	.160	↓	24	3.28	.64	27.92	32.50	
	3000	Pile sod, skid steer loader	"	2,800	.009	S.Y.		.18	.03	.21	.33	
	3100	By hand	2 Clab	400	.040			.76		.76	1.28	
	4000	Remove sod, F.E. loader	B-10S	2,000	.006			.14	.16	.30	.39	
	4100	Sod cutter	B-12K	3,200	.005			.12	.26	.38	.48	
	4200	By hand	2 Clab	240	.067	↓		1.27		1.27	2.13	

029 300 | Lawns & Grasses

		029 300 Lawns & Grasses	Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P	
308	0010	SEEDING Athletic field mix, 8#/M.S.F., push spreader R029-310	A-1	10	.800	M.S.F.	11.80	15.20	5.85	32.85	45	308
	0100	Tractor spreader	B-66	52	.154		11.80	3.60	3.51	18.91	22.50	
	0200	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	0400	Birdsfoot trefoil, .45#/M.S.F., push spreader	A-1	10	.800		13.95	15.20	5.85	35	47.50	
	0500	Tractor spreader	B-66	52	.154		13.95	3.60	3.51	21.06	25	
	0600	Hydro or air seeding,with mulch & fertil.	B-81	80	.300		28.50	6.30	6.90	41.70	49.50	
	0800	Bluegrass, 4#/M.S.F., common, push spreader	A-1	10	.800		5.05	15.20	5.85	26.10	37.50	
	0900	Tractor spreader	B-66	52	.154		5.05	3.60	3.51	12.16	15.20	
→	1000	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		19.15	6.30	6.90	32.35	39	←
	1100	Baron, push spreader	A-1	10	.800		10.60	15.20	5.85	31.65	43.50	
	1200	Tractor spreader	B-66	52	.154		10.60	3.60	3.51	17.71	21.50	
	1300	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	1500	Clover, 0.67#/M.S.F., white, push spreader	A-1	10	.800		2.50	15.20	5.85	23.55	34.50	
	1600	Tractor spreader	B-66	52	.154		2.50	3.60	3.51	9.61	12.40	
	1700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		16.65	6.30	6.90	29.85	36.50	
	1800	Ladino, push spreader	A-1	10	.800		4.23	15.20	5.85	25.28	36.50	
	1900	Tractor spreader	B-66	52	.154		4.23	3.60	3.51	11.34	14.30	
	2000	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		18.20	6.30	6.90	31.40	38	
	2200	Fescue 5.5#/M.S.F., tall, push spreader	A-1	10	.800		7.35	15.20	5.85	28.40	40	
	2300	Tractor spreader	B-66	52	.154		7.35	3.60	3.51	14.46	17.70	
	2400	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		22.50	6.30	6.90	35.70	42.50	
	2500	Chewing, push spreader	A-1	10	.800		8.55	15.20	5.85	29.60	41.50	
	2600	Tractor spreader	B-66	52	.154		8.55	3.60	3.51	15.66	19.05	
	2700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		23.50	6.30	6.90	36.70	43.50	
	2900	Crown vetch, 4#/M.S.F., push spreader	A-1	10	.800		38.50	15.20	5.85	59.55	74.50	
	3000	Tractor spreader	B-66	52	.154		38.50	3.60	3.51	45.61	52	
	3100	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		53	6.30	6.90	66.20	76	
	3300	Rye, 10#/M.S.F., annual, push spreader	A-1	10	.800		4.83	15.20	5.85	25.88	37	
	3400	Tractor spreader	B-66	52	.154		4.83	3.60	3.51	11.94	14.95	
	3500	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300	↓	18.25	6.30	6.90	31.45	38	

B-73

ICF KAISER ENGINEERS

JOB No. 04302 40300

SHEET 1 OF 1

Alternative D3 Bioslurry

Treated Soil Disposal

DESIGNED BY RRL DATE 9/1/94

CHECKED BY RDR DATE 9/1/94

1) Treated Soil from Storage to On-Site Landfill

Loading of the treated soil into 12yd³ dumptrucks will be performed with a 1½ yd³ front end loaders. Trucks will travel a 4 mile round trip.

Unit Costs Front End Loader = $1.20/yd³
12yd³ Dump Truck = $4.54/yd³
$5.74

Cost = (31,000 yd³)($5.74) = $177,940 ~ $178,000

2) Backfill and Compact Treated Soil

Backfilling will be performed with a 50' haul, 4" lifts with 4 passes of the compactor

Unit Cost = $6.07/yd³

Cost = (34,000 yd³)($6.07/yd³) = $206,380 ~ $207,000

Total Cost = $178,000 + $207,000 = $\boxed{\$385,000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

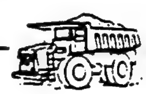
022 200 | Excav./Backfill/Compact.

			Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
234	4500	City block within zone of influence, minimum	A-8	25,200	.001	S.F.		.03		.03	.04	234
	4600	Maximum	"	15,100	.002	"		.04		.04	.07	
	5000	Excavate and load boulders, less than 0.5 C.Y.	B-10T	80	.150	C.Y.		3.39	5.45	8.84	11.25	
	5020	0.5 C.Y. to 1 C.Y.	B-10U	100	.120			2.71	9.15	11.86	14.25	
	5200	Excavate and load blasted rock, 3 C.Y. power shovel	B-12T	1,530	.010			.24	.70	.94	1.14	
	5400	Haul boulders, 25 Ton off-highway dump, 1 mile round trip	B-34E	330	.024			.48	1.81	2.29	2.73	
	5420	2 mile round trip		275	.029			.57	2.17	2.74	3.27	
	5440	3 mile round trip		225	.036			.70	2.65	3.35	4	
	5460	4 mile round trip		200	.040			.79	2.98	3.77	4.49	
	5600	Bury boulders on site, less than 0.5 C.Y., 300 H.P. dozer										
	5620	150' haul	B-10M	310	.039	C.Y.		.87	3.21	4.08	4.88	
	5640	300' haul		210	.057			1.29	4.74	6.03	7.20	
	5800	0.5 to 1 C.Y., 300 H.P. dozer, 150' haul		300	.040			.90	3.32	4.22	5.05	
	5820	300' haul		200	.060			1.35	4.98	6.33	7.60	
238	0010	EXCAVATING, BULK BANK MEASURE Common earth piled R022-240										238
	0020	For loading onto trucks, add								15%	15%	
	0050	For mobilization and demobilization, see division 022-274 R022-250										
	0100	For hauling, see division 022-266										
	0200	Backhoe, hydraulic, crawler mtd., 1 C.Y. cap. = 75 C.Y./hr.	B-12A	600	.027	C.Y.		.52	.98	1.50	1.91	
	0250	1-1/2 C.Y. cap. = 100 C.Y./hr.	B-12B	800	.020			.46	.85	1.31	1.65	
	0260	2 C.Y. cap. = 130 C.Y./hr.	B-12C	1,040	.015			.36	.90	1.26	1.53	
	0300	3 C.Y. cap. = 160 C.Y./hr.	B-12D	1,620	.010			.23	1.29	1.52	1.77	
	0310	Wheel mounted, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12E	240	.067			1.54	1.33	2.87	3.82	
	0360	3/4 C.Y. cap. = 45 C.Y./hr.	B-12F	360	.044			1.03	1.20	2.23	2.89	
	0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr.	B-12G	160	.100			2.31	2.82	5.13	6.65	
	0550	1 C.Y. cap. = 35 C.Y./hr.	B-12H	280	.057			1.32	1.91	3.23	4.12	
	0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.	B-12I	240	.067			1.54	1.95	3.49	4.50	
	1000	Dragline, 3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1001	3/4 C.Y. cap. = 35 C.Y./hr.		280	.057			1.32	1.67	2.99	3.86	
	1050	1-1/2 C.Y. cap. = 65 C.Y./hr.	B-12P	520	.031			.71	1.46	2.17	2.69	
	1100	3 C.Y. cap. = 112 C.Y./hr.	B-12V	900	.018			.41	.98	1.39	1.71	
	1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.	B-10N	560	.021			.48	.62	1.10	1.44	
	1250	2-1/2 C.Y. cap. = 95 C.Y./hr.	B-10O	760	.016			.36	.62	.98	1.23	
	1300	3 C.Y. cap. = 130 C.Y./hr.	B-10P	1,040	.012			.26	.75	1.01	1.23	
	1350	5 C.Y. cap. = 160 C.Y./hr.	B-10Q	1,620	.007			.17	.67	.84	1	
	1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.	B-10R	360	.033			.75	.62	1.37	1.84	
	1550	1-1/2 C.Y. cap. = 80 C.Y./hr.	B-10S	640	.019			.42	.50	.92	1.20	
	1600	2-1/4 C.Y. cap. = 100 C.Y./hr.	B-10T	800	.015			.34	.54	.88	1.12	
	1601	3 C.Y. cap. = 100 C.Y./hr.	"	1,100	.011			.25	.40	.65	.82	
	1650	5 C.Y. cap. = 185 C.Y./hr.	B-10U	1,480	.008			.18	.62	.80	.96	
	1800	Hydraulic excavator, truck mtd, 1/2 C.Y. = 30 C.Y./hr.	B-12J	240	.067			1.54	2.52	4.06	5.15	
	1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.	B-12K	360	.044			1.03	2.31	3.34	4.11	
	3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.	B-12L	440	.036			.84	1.04	1.88	2.44	
	3750	3/4 C.Y. capacity = 85 C.Y./hr.	B-12M	680	.024			.54	.78	1.32	1.69	
	3800	1 C.Y. capacity = 120 C.Y./hr.	B-12N	960	.017			.38	.63	1.01	1.28	
	3850	1-1/2 C.Y. capacity = 160 C.Y./hr.	B-12O	1,280	.013			.29	.67	.96	1.18	
	3900	3 C.Y. cap. = 250 C.Y./hr.	B-12T	2,000	.008			.18	.54	.72	.87	
	4000	For soft soil or sand, deduct								15%	15%	
	4100	For heavy soil or stiff clay, add								60%	60%	
	4200	For wet excavation with clamshell or dragline, add								100%	100%	
	4250	All other equipment, add								50%	50%	
	4400	Clamshell in sheeting or cofferdam, minimum	B-12H	160	.100			2.31	3.33	5.64	7.20	
	4450	Maximum	"	60	.267			6.15	8.90	15.05	19.25	
	8000	For hauling excavated material, see div. 022-266										
242	0010	EXCAVATING, BULK, DOZER Open site										242
	2000	75 H.P., 50' haul, sand & gravel	B-10L	460	.026	C.Y.		.59	.59	1.18	1.56	

B-75

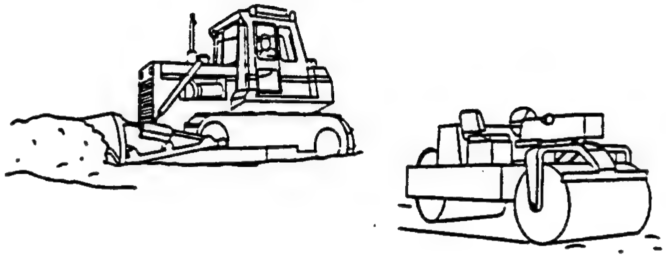
022 200 | Excav./Backfill/Compact.

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
252	0150	Spread fill, from stockpile with 2-1/2 C.Y. F.E. loader									
	0170	130 H.P. 300' haul	B-10P	600	.020	C.Y.		.45	1.31	1.76	2.14
	0190	With dozer 300 H.P. 300' haul	B-10M	600	.020	"		.45	1.66	2.11	2.53
	0400	For compaction of embankment, see div. 022-226									
	0500	Gravel fill, compacted, under floor slabs, 4" deep	B-37	10,000	.005	S.F.	.10	.10	.01	.21	27
	0600	6" deep		8,600	.006		.15	.11	.02	.28	.37
	0700	9" deep		7,200	.007		.25	.13	02	.40	.51
	0800	12" deep		6,000	.008		.35	.16	.02	.53	.66
	1000	Alternate pricing method, 4" deep		120	.400	C.Y.	7.50	8.05	1.13	16.68	22
	1100	6" deep		160	.300		7.50	6	.85	14.35	18.70
	1200	9" deep		200	.240		7.50	4.82	.68	13	16.60
	1300	12" deep		220	.218		7.50	4.38	.62	12.50	15.85
	1500	For fill under exterior paving, see division 022-308									
256	0011	HAULING Excavated or borrow material, highway haulers R022-240									
	0012	bank measure, no loading included									
	0020	6 C.Y. dump truck, 1/4 mile round trip, 5.0 loads/hr.	B-34A	240	.033	C.Y.		.66	1.35	2.01	2.50
	0030	1/2 mile round trip, 4.1 loads/hr.		197	.041			.80	1.65	2.45	3.04
	0040	1 mile round trip, 3.3 loads/hr.		160	.050			.99	2.03	3.02	3.75
	0100	2 mile round trip, 2.6 loads/hr.		125	.064			1.26	2.60	3.86	4.80
	0150	3 mile round trip, 2.1 loads/hr.		100	.080			1.58	3.25	4.83	6
	0200	4 mile round trip, 1.8 loads/hr.		85	.094			1.85	3.52	5.37	7.05
	0310	12 C.Y. dump truck, 1/4 mile round trip 3.7 loads/hr.	B-34B	356	.022			.44	1.12	1.56	1.91
	0320	1/2 mile round trip, 3.2 loads/hr.		308	.026			.51	1.29	1.80	2.21
	0330	1 mile round trip 2.7 loads/hr.		260	.031			.61	1.53	2.14	2.62
	0400	2 mile round trip, 2.2 loads/hr.		210	.038			.75	1.90	2.65	3.25
	0450	3 mile round trip, 1.9 loads/hr.		180	.044			.88	2.21	3.09	3.79
	0500	4 mile round trip, 1.6 loads/hr.		150	.053			1.05	2.66	3.71	4.54
	0540	5 mile round trip, 1 load/hr.		98	.082			1.61	4.07	5.68	6.95
	0550	10 mile round trip, 0.75 load/hr.		49	.163			3.22	8.15	11.37	13.90
	0560	20 mile round trip, 0.5 load/hr.		32	.250			4.93	12.45	17.38	21.50
	0600	16.5 C.Y. dump trailer, 1 mile round trip, 2.6 loads/hr.	B-34C	340	.024			.46	1.45	1.91	2.31
	0700	2 mile round trip, 2.1 loads/hr.		275	.029			.57	1.79	2.36	2.85
	1000	3 mile round trip, 1.8 loads/hr.		235	.034			.67	2.10	2.77	3.34
	1100	4 mile round trip, 1.6 loads/hr.		210	.038			.75	2.35	3.10	3.75
	1110	5 mile round trip, 1 load/hr.		132	.061			1.19	3.74	4.93	5.95
	1120	10 mile round trip, .75 load/hr.		100	.080			1.58	4.94	6.52	7.90
	1130	20 mile round trip, .5 load/hr.		66	.121			2.39	7.50	9.89	11.95
	1150	20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr.	B-34D	400	.020			.39	1.24	1.63	1.97
	1200	2 mile round trip, 2 loads/hr.		320	.025			.49	1.55	2.04	2.46
	1220	3 mile round trip, 1.7 loads/hr.		270	.030			.58	1.83	2.41	2.92
	1240	4 mile round trip, 1.5 loads/hr.		240	.033			.66	2.06	2.72	3.28
	1245	5 mile round trip, 1.1 load/hr.		172	.047			.92	2.88	3.80	4.57
	1250	10 mile round trip, .85 load/hr.		136	.059			1.16	3.64	4.80	5.80
	1255	20 mile round trip, .6 load/hr.		96	.083			1.64	5.15	6.79	8.20
	1300	Hauling in medium traffic, add								20%	20%
	1400	Heavy traffic, add								30%	30%
	1600	Grading at dump, or embankment if required, by dozer	B-10B	1,000	.012			.27	.82	1.09	1.32
	1800	Spotter at fill or cut, if required	1 Clab	8	1	Hr.		19		19	30
	2000	Off highway haulers									
	2010	22 C.Y. rear or bottom dump, 1000' round trip, 4.5 loads/hr.	B-34F	800	.010	C.Y.		.20	1.17	1.37	1.58
	2020	1/2 mile round trip, 4.2 loads/hr.		740	.011			.21	1.26	1.47	1.72
	2030	1 mile round trip, 3.9 loads/hr.		685	.012			.23	1.36	1.59	1.85
	2040	2 mile round trip, 3.3 loads/hr.		580	.014			.27	1.61	1.88	2.19
	2050	34 C.Y. rear or bottom dump, 1000' round trip, 4 loads/hr.	B-34G	1,090	.007			.14	1.14	1.28	1.48
	2060	1/2 mile round trip, 3.8 loads/hr.		1,035	.008			.15	1.20	1.35	1.55



See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-76



The Common Earth Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Common Earth Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-724-1000					
EARTH BACKFILL, 75 HP DOZER & ROLLER, 50' HAUL, 4"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul. common earth, from stockpile	1.000	C.Y.	.31	.43	.74
Water wagon, rent per day	.004	Hr.	.27	.12	.39
Compaction, roller, 4" lifts, 2 passes	.035	Hr.	.65	1.84	2.49
Total			1.23	2.39	3.62

12.1-724	Common Earth Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Earth backfill,75 HP dozer & roller compactors,50' haul,4" lifts,2 passes	1.23	2.39	3.62
1050	4 passes	1.88	4.23	6.11
1100	8" lifts, 2 passes	.91	1.50	2.41
1150	4 passes	1.23	2.39	3.62
1200	150' haul, 4" lifts, 2 passes	1.53	2.82	4.35
1250	4 passes	2.18	4.66	6.84
1300	8" lifts, 2 passes	1.21	1.93	3.14
1350	4 passes	1.53	2.82	4.35
1400	300' haul, 4" lifts, 2 passes	1.83	3.23	5.06
1450	4 passes	2.48	5.05	7.53
1500	8" lifts, 2 passes	1.51	2.34	3.85
1550	4 passes	1.83	3.23	5.06
1600	105 HP dozer & roller compactors, 50' haul, 4" lifts, 2 passes	1.28	2.30	3.58
1650	4 passes	1.93	4.14	6.07
1700	8" lifts, 2 passes	.96	1.41	2.37
1750	4 passes	1.28	2.30	3.58
1800	150' haul, 4" lifts, 2 passes	1.65	2.65	4.30
1850	4 passes	2.30	4.49	6.79
1900	8" lifts, 2 passes	1.33	1.76	3.09
1950	4 passes	1.65	2.65	4.30
2000	300' haul, 4" lifts, 2 passes	1.99	2.97	4.96
2050	4 passes	2.64	4.81	7.45
2100	8" lifts, 2 passes	1.67	2.08	3.75
2150	4 passes	1.99	2.97	4.96
2200	200 HP dozer & roller compactors, 150' haul, 4" lifts, 2 passes	1.70	1.55	3.25
2250	4 passes	2.31	2.60	4.91
2300	8" lifts, 2 passes	1.40	1.03	2.43
2350	4 passes	1.70	1.55	3.25
2600	300' haul, 4" lifts, 2 passes	2.11	1.74	3.85
2650	4 passes	2.72	2.79	5.51
2700	8" lifts, 2 passes	1.81	1.22	3.03
2750	4 passes	2.11	1.74	3.85

B-77

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

ICF KAISER ENGINEERS

Job No. 0430240300

Sheet 1 of 1

Alternative D8 Bioslurry

Landfill / Liner System

DESIGNED BY RBL DATE 9/1/9

CHECKED BY RCB DATE 9/1/94

22,200 yd^3 of Soil will be treated by Bioslurry Treatment The final Volume will be 34,000. Landfill depth will be 10 feet with a 3 foot clay liner for a total of 13 feet

Landfill Surface area = 94,000 ft^2 ~ 2.2 ac

Landfill Size = 306' x 306' x 13'

Clay for Liner to be taken from on-site Borrow Area

$$\text{Volume} = \underbrace{(94{,}000\ ft^2)(3\ ft)\left(\frac{1\ yd^3}{27\ ft^3}\right)}_{\text{Base}} + \underbrace{4(3\ ft \times 13\ ft \times 306\ ft)\left(\frac{1\ yd^3}{27\ ft^3}\right)}_{\text{walls}}$$
$$\sim 12000\ yd^3$$

1) Clay Excavation for Liner

1/2 yd^3 backhoe and 6-12 yd^3 dumptrucks, 4 mile round trip

Unit Cost = \$7.93/yd^3

Cost = (12,000 yd^3)(\$7.93/yd^3) = \$95,160 ~ \$96,000

2) Clay Backfill and Compaction

Clay will be backfilled w/a 200 hp Bulldozer in 4" lifts
Clay will be compacted w/a sheepsfoot compactor

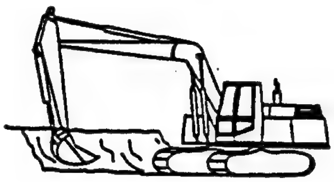
Unit Cost = \$2.51/yd^3

Cost = (12,000 yd^3)(\$2.51/yd^3) = \$30,000

Total Cost = \$96,000 + \$30,000 = $\boxed{\$126{,}000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Excavate Clay



The Excavation of Clay System balances the productivity of excavating equipment to hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 40%.

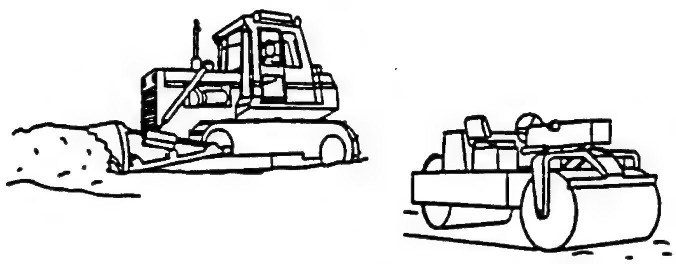
The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 1-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-416-1000					
EXCAVATE CLAY, 1/2 $FF3CY BACKHOE, TWO 6 CY DUMP TRUCKS,2 MI ROUND TRIP					
Excavating bulk hyd. backhoe, wheel mtd. 1/2 C.Y.	1.000	C.Y.	1.31	2.12	3.43
Haul earth, 6 C.Y. dump truck, 2 mile round trip, 2.6 loads/hr	1.000	C.Y.	4	2.72	6.72
Spotter at earth fill dump or in cut	.020	Hr.		.69	.69
Total			5.31	5.53	10.84

12.1-416	Excavate Clay	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Excavate clay, 1/2C.Y. backhoe, two 6C.Y. dump trucks, 2mile round trip	5.30	5.55	10.85
1200	Three 6 C.Y. dump trucks, 4 mile round trip	7.15	6.70	13.85
1400	Two 12 C.Y. dump trucks, 4 mile round trip	5.15	4.54	9.69
1600	3/4 C.Y. backhoe, three 6 C.Y. dump trucks, 2 mile round trip	5.20	4.58	9.78
1700	Five 6 C.Y. dump trucks, 4 mile round trip	6.90	5.60	12.50
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.98	3.26	7.24
1900	Three 12 C.Y. dump trucks, 4 mile round trip	5.05	3.77	8.82
2000	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.80	4.20	10
2100	Three 12 C.Y. dump trucks, 1 mile round trip	3.18	2.12	5.30
2200	Six 12 C.Y. dump trucks, 4 mile round trip	4.78	3.15	7.93
2300	Three 16 C.Y. dump trailers, 2 mile round trip	3.52	2.01	5.53
2400	Four 16 C.Y. dump trailers, 4 mile round trip	4.38	2.40	6.78
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.69	1.66	4.35
2800	2-1/2 C.Y. backhoe, eight 12 C.Y. dump trucks, 3 mile round trip	3.99	2.44	6.43
2900	Four 16 C.Y. dump trailers, 1 mile round trip	2.84	1.44	4.28
3000	Six 16 C.Y. dump trailers, 3 mile round trip	3.81	2	5.81
3100	Four 20 C.Y. dump trailers, 2 mile round trip	2.96	1.62	4.58
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.76	1.97	5.73
3400	3-1/2 C.Y. backhoe, ten 12 C.Y. dump trucks, 2 mile round trip	4.06	2.05	6.11
3500	Six 16 C.Y. dump trailers, 1 mile round trip	3.40	1.43	4.83
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.76	2.05	6.81
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.93	1.68	5.61
4000	1/2 C.Y. pwr. shovel, three 6 C.Y. dump trucks, 1 mile round trip	2.87	2.61	5.48
4100	Six 6 C.Y. dump trucks, 4 mile round trip	6.65	5.50	12.15
4200	Two 12 C.Y. dump trucks, 1 mile round trip	3.12	2.47	5.59
4400	Three 12 C.Y. dump trucks, 3 mile round trip	4.13	2.98	7.11
4600	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.64	3.79	8.43
4700	Nine 6 C.Y. dump trucks, 4 mile round trip	6.50	5	11.50
4800	Three 12 C.Y. dump trucks, 1 mile round trip	2.99	2.11	5.10
4900	Four 12 C.Y. dump trucks, 3 mile round trip	4.08	2.77	6.85
5000	Two 16 C.Y. dump trailers, 1 mile round trip	2.94	1.91	4.85
5200	Three 16 C.Y. dump trailers, 3 mile round trip	3.91	2.33	6.24
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 2 mile round trip	3.52	2.24	5.76
5500	Four 16 C.Y. dump trailers, 1 mile round trip	2.78	1.43	4.21

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-79



The Clay Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Clay Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-726-1000					
CLAY BACKFILL, 75 HP DOZER & TAMPER, 50' HAUL, 6"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, clay from stockpile	1.000	C.Y.	.35	.49	.84
Water wagon rent per day	.004	Hr.	.27	.12	.39
Compaction, tamper, 4" lifts, 2 passes	1.000	C.Y.	.16	.62	.78
Total			.78	1.23	2.01

12.1-726	Clay Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Clay backfill, 75 HP dozer & tamper compactors, 50'haul,4"lifts, 2 passes	.78	1.23	2.01
1050	4 passes	.95	1.84	2.79
1100	8" lifts, 2 passes	.70	.92	1.62
1150	4 passes	.78	1.23	2.01
1200	150' haul, 4" lifts, 2 passes	1.13	1.73	2.86
1250	4 passes	1.30	2.34	3.64
1300	8" lifts, 2 passes	1.05	1.42	2.47
1350	4 passes	1.13	1.73	2.86
1400	300' haul, 4" lifts, 2 passes	1.46	2.19	3.65
1450	4 passes	1.63	2.80	4.43
1500	8" lifts, passes	1.38	1.88	3.26
1550	Passes	1.46	2.19	3.65
1600	105 HP dozer & tamper compactors, 50' haul, 4" lifts, 2 passes	.83	1.12	1.95
1650	4 passes	1	1.73	2.73
1700	8" lifts, 2 passes	.75	.81	1.56
1750	4 passes	.83	1.12	1.95
1800	150' haul, 4" lifts, 2 passes	1.24	1.50	2.74
1850	4 passes	1.41	2.11	3.52
1900	8" lifts, 2 passes	1.16	1.19	2.35
1950	4 passes	1.24	1.50	2.74
2000	300' haul, 4" lifts, 2 passes	1.63	1.87	3.50
2050	4 passes	1.80	2.48	4.28
2100	8" lifts, 2 passes	1.55	1.56	3.11
2150	4 passes	1.63	1.87	3.50
2200	200 HP dozer & sheepsfoot compactors, 150' haul, 5" lifts, 2 passes	1.41	.71	2.12
2250	4 passes	1.64	.87	2.51
2300	8" lifts, 2 passes	1.30	.63	1.93
2350	4 passes	1.41	.71	2.12
2600	300' haul, 4" lifts, 2 passes	1.86	.92	2.78
2650	4 passes	2.09	1.08	3.17
2700	8" lifts, 2 passes	1.75	.84	2.59
2750	4 passes	1.86	.92	2.78

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-80

ICF KAISER ENGINEERS

Job No. 0430240300

Sheet 1 of 2

Alternative O: Bioslurry

Landfill Cap

DESIGNED BY RRL DATE 9/11

CHECKED BY RDB DATE 9/1/12

Construction of the landfill cap will consist of a 30-inch layer of compacted clay covered with an 8-inch layer of topsoil. Once constructed, the cap will be revegetated. Costs include one upgradient and two downgradient monitoring wells. 2.5 acre area to cover edges of landfill

1) Clay Layer

$$\text{Volume} = (2.5\text{ acres})\left(\frac{43560\text{ ft}^2}{\text{acre}}\right)\left(\frac{30''}{12''/\text{ft}}\right)\left(\frac{1\text{ yd}^3}{27\text{ ft}^3}\right) = 10{,}083 \sim 10{,}100\text{ yd}^3$$

Unit Cost: Excavate and Haul = \$7.93/yd³

Backfill and Compact = \$2.51/yd³

\$10.44/yd³

$$\text{Cost} = (10{,}100\text{ yd}^3)(\$10.44/\text{yd}^3) = \$105{,}444 \sim \$106{,}000$$

2) Topsoil Layer

$$\text{Volume} = (2.5\text{ acres})\left(\frac{43560\text{ ft}^2}{\text{acre}}\right)\left(\frac{8''}{12''/\text{ft}}\right)\left(\frac{1\text{ yd}^3}{27\text{ ft}^3}\right) = 2689 \sim 2700\text{ yd}^3$$

Unit Cost = Excavate and Haul = \$7.08/yd³

Backfill \$1.20/yd³

\$8.28/yd³

$$\text{Cost} = (2700\text{ yd}^3)(\$8.28/\text{yd}^3) = \$22{,}356 \sim \$23{,}000$$

3) Revegetate

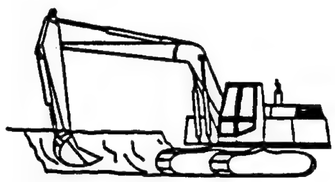
Revegetation will include hydroseeding w/mulch and fertilizer

Unit Cost = \$39/1000 ft²

$$\text{Cost} = (2.5\text{ ac})\left(\frac{43560\text{ ft}^2}{\text{ac}}\right)(\$39/1000\text{ ft}^2) = \$4247 \sim \$5000$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Excavate Clay



The Excavation of Clay System balances the productivity of excavating equipment to hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 40%.

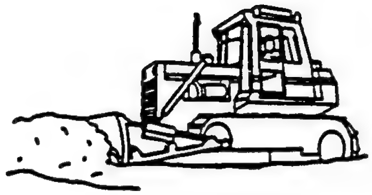
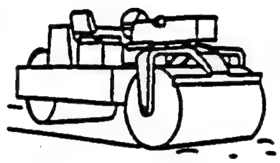
The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 1-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
SYSTEM 12.1-416-1000					
EXCAVATE CLAY, 1/2 $FF3CY BACKHOE, TWO 6 CY DUMP TRUCKS,2 MI ROUND TRIP					
Excavating bulk hyd. backhoe, wheel mtd. 1/2 C.Y.	1.000	C.Y.	1.31	2.12	3.43
Haul earth, 6 C.Y. dump truck, 2 mile round trip, 2.6 loads/hr	1.000	C.Y.	4	2.72	6.72
Spotter at earth fill dump or in cut	.020	Hr.		.69	.69
Total			5.31	5.53	10.84

12.1-416	Excavate Clay	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
1000	Excavate clay, 1/2C.Y. backhoe, two 6C.Y. dump trucks, 2mile round trip	5.30	5.55	10.85
1200	Three 6 C.Y. dump trucks, 4 mile round trip	7.15	6.70	13.85
1400	Two 12 C.Y. dump trucks, 4 mile round trip	5.15	4.54	9.69
1600	3/4 C.Y. backhoe, three 6 C.Y. dump trucks, 2 mile round trip	5.20	4.58	9.78
1700	Five 6 C.Y. dump trucks, 4 mile round trip	6.90	5.60	12.50
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.98	3.26	7.24
1900	Three 12 C.Y. dump trucks, 4 mile round trip	5.05	3.77	8.82
2000	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.80	4.20	10
2100	Three 12 C.Y. dump trucks, 1 mile round trip	3.18	2.12	5.30
2200	Six 12 C.Y. dump trucks, 4 mile round trip	4.78	3.15	7.93
2300	Three 16 C.Y. dump trailers, 2 mile round trip	3.52	2.01	5.53
2400	Four 16 C.Y. dump trailers, 4 mile round trip	4.38	2.40	6.78
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.69	1.66	4.35
2800	2-1/2 C.Y. backhoe, eight 12 C.Y. dump trucks, 3 mile round trip	3.99	2.44	6.43
2900	Four 16 C.Y. dump trailers, 1 mile round trip	2.84	1.44	4.28
3000	Six 16 C.Y. dump trailers, 3 mile round trip	3.81	2	5.81
3100	Four 20 C.Y. dump trailers, 2 mile round trip	2.96	1.62	4.58
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.76	1.97	5.73
3400	3-1/2 C.Y. backhoe, ten 12 C.Y. dump trucks, 2 mile round trip	4.06	2.05	6.11
3500	Six 16 C.Y. dump trailers, 1 mile round trip	3.40	1.43	4.83
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.76	2.05	6.81
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.93	1.68	5.61
4000	1/2 C.Y. pwr. shovel, three 6 C.Y. dump trucks, 1 mile round trip	2.87	2.61	5.48
4100	Six 6 C.Y. dump trucks, 4 mile round trip	6.65	5.50	12.15
4200	Two 12 C.Y. dump trucks, 1 mile round trip	3.12	2.47	5.59
4400	Three 12 C.Y. dump trucks, 3 mile round trip	4.13	2.98	7.11
4600	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.64	3.79	8.43
4700	Nine 6 C.Y. dump trucks, 4 mile round trip	6.50	5	11.50
4800	Three 12 C.Y. dump trucks, 1 mile round trip	2.99	2.11	5.10
4900	Four 12 C.Y. dump trucks, 3 mile round trip	4.08	2.77	6.85
5000	Two 16 C.Y. dump trailers, 1 mile round trip	2.94	1.91	4.85
5200	Three 16 C.Y. dump trailers, 3 mile round trip	3.91	2.33	6.24
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 2 mile round trip	3.52	2.24	5.76
5500	Four 16 C.Y. dump trailers, 1 mile round trip	2.78	1.43	4.21

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-82

The Clay Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

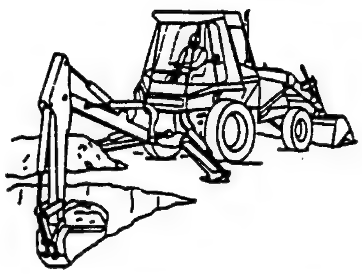
The Expanded System Listing shows Clay Backfilling with bulldozers ranging from 75 H.P. to 300 H.P. The maximum distance ranges from 50' to 300'. Lifts for the compaction range from 4" to 8". There is no waste included in the assumptions.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-726-1000					
CLAY BACKFILL, 75 HP DOZER & TAMPER, 50' HAUL, 6"LIFTS, 2 PASSES					
Backfilling, dozer 75 H.P. 50' haul, clay from stockpile	1.000	C.Y.	.35	.49	.84
Water wagon rent per day	.004	Hr.	.27	.12	.39
Compaction, tamper, 4" lifts, 2 passes	1.000	C.Y.	.16	.62	.78
Total			.78	1.23	2.01

12.1-726	Clay Backfill	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Clay backfill, 75 HP dozer & tamper compactors, 50'haul, 4"lifts, 2 passes	.78	1.23	2.01
1050	4 passes	.95	1.84	2.79
1100	8" lifts, 2 passes	.70	.92	1.62
1150	4 passes	.78	1.23	2.01
1200	150' haul, 4" lifts, 2 passes	1.13	1.73	2.86
1250	4 passes	1.30	2.34	3.64
1300	8" lifts, 2 passes	1.05	1.42	2.47
1350	4 passes	1.13	1.73	2.86
1400	300' haul, 4" lifts, 2 passes	1.46	2.19	3.65
1450	4 passes	1.63	2.80	4.43
1500	8" lifts, passes	1.38	1.88	3.26
1550	Passes	1.46	2.19	3.65
1600	105 HP dozer & tamper compactors, 50' haul, 4" lifts, 2 passes	.83	1.12	1.95
1650	4 passes	1	1.73	2.73
1700	8" lifts, 2 passes	.75	.81	1.56
1750	4 passes	.83	1.12	1.95
1800	150' haul, 4" lifts, 2 passes	1.24	1.50	2.74
1850	4 passes	1.41	2.11	3.52
1900	8" lifts, 2 passes	1.16	1.19	2.35
1950	4 passes	1.24	1.50	2.74
2000	300' haul, 4" lifts, 2 passes	1.63	1.87	3.50
2050	4 passes	1.80	2.48	4.28
2100	8" lifts, 2 passes	1.55	1.56	3.11
2150	4 passes	1.63	1.87	3.50
2200	200 HP dozer & sheepsfoot compactors, 150' haul, 5" lifts, 2 passes	1.41	.71	2.12
2250	4 passes	1.64	.87	2.51
2300	8" lifts, 2 passes	1.30	.63	1.93
2350	4 passes	1.41	.71	2.12
2600	300' haul, 4" lifts, 2 passes	1.86	.92	2.78
2650	4 passes	2.09	1.08	3.17
2700	8" lifts, 2 passes	1.75	.84	2.59
2750	4 passes	1.86	.92	2.78

13-83

See the Reference Section for reference number information, Crew Listings and City Cost Indexes



The Excavation of Common Earth System balances the productivity of the excavating equipment to the hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route. No mobilization cost is included. All costs given in these systems include a swell factor of 25% for hauling.

The Expanded System Listing shows Excavation systems using backhoes ranging from 1/2 Cubic Yard capacity to 3-1/2 Cubic Yards. Power shovels indicated range from 1/2 Cubic Yard to 3 Cubic Yards. Dragline bucket rigs range from 1/2 Cubic Yard to 3 Cubic Yards. Truck capacities range from 6 Cubic Yards to 20 Cubic Yards. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	LABOR	TOTAL
SYSTEM 12.1-414-1000					
EXCAVATE COMMON EARTH, 1/2 SFF3 CY BACKHOE, TWO 6 CY DUMP TRUCKS, 1 MRT					
Excavating, bulk hyd. backhoe wheel mtd., 1/2 C.Y.	1.000	C.Y.	.92	1.49	2.41
Haul earth, 6 C.Y. dump truck, 1 mile round trip, 3.3 loads/hr	1.000	C.Y.	1.86	1.26	3.12
Spotter at earth fill dump or in cut	.020	Hr.		.48	.48
Total			2.78	3.23	6.01

12.1-414	Excavate Common Earth	COST PER C.Y. EQUIP.	LABOR	TOTAL
1000	Excavate common earth, 1/2 C.Y. backhoe,two 6 C.Y. dump trucks, 1MRT	2.78	3.23	6.01
1200	Three 6 C.Y. dump trucks, 3 mile round trip	5.45	5.10	10.55
1400	Two 12 C.Y. dump trucks, 4 mile round trip	4.60	4.05	8.65
1600	3/4 C.Y. backhoe, three C.Y. dump trucks, 1 mile round trip	2.69	2.58	5.27
1700	Five 6 C.Y. dump trucks, 3 mile round trip	5.25	4.58	9.83
1800	Two 12 C.Y. dump trucks, 2 mile round trip	3.55	2.93	6.48
1900	Two 16 C.Y. dump trailers, 3 mile round trip	3.61	2.41	6.02
2000	Two 20 C.Y. dump trailers, 4 mile round trip	3.67	2.54	6.21
2200	1-1/2 C.Y. backhoe, eight 6 C.Y. dump trucks, 3 mile round trip	5.15	3.92	9.07
2300	Four 12 C.Y. dump trucks, 2 mile round trip	3.27	2.31	5.58
2400	Six 12 C.Y. dump trucks, 4 mile round trip	4.26	2.82	7.08
2500	Three 16 C.Y. dump trailers, 2 mile round trip	3.14	1.79	4.93
2600	Two 20 C.Y. dump trailers, 1 mile round trip	2.41	1.47	3.88
2700	Three 20 C.Y. dump trailer, 3 mile round trip	3.22	1.83	5.05
2800	2-1/2 C.Y. backhoe, six 12 C.Y. dump trucks, 1 mile round trip	2.59	1.60	4.19
2900	Eight 12 C.Y. dump trucks, 3 mile round trip	3.56	2.18	5.74
3000	Four 16 C.Y. dump trailers, 1 mile round trip	2.54	1.30	3.84
3100	Six 16 C.Y. dump trailers, 3 mile round trip	3.41	1.78	5.19
3200	Six 20 C.Y. dump trailers, 4 mile round trip	3.36	1.75	5.11
3400	3-1/2 C.Y. backhoe, six 16 C.Y. dump trailers, 1 mile round trip	3.03	1.29	4.32
3600	Ten 16 C.Y. dump trailers, 4 mile round trip	4.25	1.85	6.10
3800	Eight 20 C.Y. dump trailers, 3 mile round trip	3.51	1.52	5.03
4000	1/2 C.Y. pwr. shovel, four 6 C.Y. dump trucks, 2 mile round trip	4.27	3.50	7.77
4100	Two 12 C.Y. dump trucks, 1 mile round trip	2.77	2.21	4.98
4200	Four 12 C.Y. dump trucks, 4 mile round trip	4.21	2.90	7.11
4300	Two 16 C.Y. dump trailers, 2 mile round trip	3.09	2.07	5.16
4400	Two 20 C.Y. dump trailers, 4 mile round trip	3.57	2.41	5.98
4500				
4800	3/4 C.Y. pwr. shovel, six 6 C.Y. dump trucks, 2 mile round trip	4.15	3.37	7.52
4900	Three 12 C.Y. dump trucks, 1 mile round trip	2.66	1.88	4.54
5000	Five 12 C.Y. dump trucks, 4 mile round trip	4.21	2.78	6.99
5100	Three 16 C.Y. dump trailers, 3 mile round trip	3.49	2.08	5.57
5200	Three 20 C.Y. dump trailers, 4 mile round trip	3.44	2.05	5.49
5400	1-1/2 C.Y. pwr. shovel, six 12 C.Y. dump trucks, 1 mile round trip	2.54	1.59	4.13

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-84

022 100 | Grading

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
104	0010	GRADING Site excav. & fill, see div 022-200									
	0020	Fine grading, see div 025-122									

022 200 | Excav./Backfill/Compact.

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
204	0010	BACKFILL By hand, no compaction, light soil (R022-220)	1 Clab	14	.571	C.Y.		10.85		10.85	17.20
	0100	Heavy soil		11	.727			13.80		13.80	22
	0300	Compaction in 6" layers, hand tamp, add to above		20.60	.388			7.40		7.40	11.70
	0400	Roller compaction operator walking, add	B-10A	100	.120			2.71	.82	3.53	5.10
	0500	Air tamp, add	B-9	190	.211			4.08	.78	4.86	7.30
	0600	Vibrating plate, add	A-1	60	.133			2.53	.97	3.50	5.10
	0800	Compaction in 12" layers, hand tamp, add to above	1 Clab	34	.235			4.47		4.47	7.10
	0900	Roller compaction operator walking, add	B-10A	150	.080			1.81	.54	2.35	3.39
	1000	Air tamp, add	B-9	285	.140			2.72	.52	3.24	4.88
	1100	Vibrating plate, add	A-1	90	.089			1.69	.65	2.34	3.39
208	0010	BACKFILL, STRUCTURAL Dozer or F.E. loader									
	0020	From existing stockpile, no compaction									
	2000	75 H.P., 50' haul, sand & gravel	B-10L	1,100	.011	C.Y.		.25	.25	.50	.65
	2020	Common earth		975	.012			.28	.28	.56	.74
	2040	Clay		850	.014			.32	.32	.64	.84
	2200	150' haul, sand & gravel		550	.022			.49	.49	.98	1.30
	2220	Common earth		490	.024			.55	.55	1.10	1.47
	2240	Clay		425	.028			.64	.64	1.28	1.69
	2400	300' haul, sand & gravel		370	.032			.73	.73	1.46	1.94
	2420	Common earth		330	.036			.82	.82	1.64	2.18
	2440	Clay		290	.041			.93	.94	1.87	2.48
	3000	105 H.P., 50' haul, sand & gravel	B-10W	1,350	.009			.20	.30	.50	.64
	3020	Common earth		1,225	.010			.22	.33	.55	.70
	3040	Clay		1,100	.011			.25	.37	.62	.78
	3200	150' haul, sand & gravel		670	.018			.40	.60	1	1.29
	3220	Common earth		610	.020			.44	.66	1.10	1.42
	3240	Clay		550	.022			.49	.73	1.22	1.57
	3300	300' haul, sand & gravel		465	.026			.58	.87	1.45	1.85
	3320	Common earth		415	.029			.65	.97	1.62	2.08
	3340	Clay		370	.032			.73	1.09	1.82	2.33
	4000	200 H.P., 50' haul, sand & gravel	B-10B	2,500	.005			.11	.33	.44	.53
	4020	Common earth		2,200	.005			.12	.37	.49	.60
	4040	Clay		1,950	.006			.14	.42	.56	.67
	4200	150' haul, sand & gravel		1,225	.010			.22	.67	.89	1.08
	4220	Common earth		1,100	.011			.25	.75	1	1.20
	4240	Clay		975	.012			.28	.84	1.12	1.35
	4400	300' haul, sand & gravel		805	.015			.34	1.02	1.36	1.64
	4420	Common earth		735	.016			.37	1.12	1.49	1.80
	4440	Clay		660	.018			.41	1.24	1.65	2.01
	5000	300 H.P., 50' haul, sand & gravel	B-10M	3,170	.004			.09	.31	.40	.48
	5020	Common earth		2,900	.004			.09	.34	.43	.52
	5040	Clay		2,700	.004			.10	.37	.47	.57
	5200	150' haul, sand & gravel		2,200	.005			.12	.45	.57	.69
	5220	Common earth		1,950	.006			.14	.51	.65	.77
	5240	Clay		1,700	.007			.16	.59	.75	.89
	5400	300' haul, sand & gravel		1,500	.008			.18	.66	.84	1.01
	5420	Common earth		1,350	.009			.20	.74	.94	1.12
	5440	Clay		1,225	.010			.22	.81	1.03	1.23
	6000	For compaction, see div. 022-226									
	6010	For trench backfill, see div. 022-254 & 258									
216	0011	BORROW Bank measure, loaded onto 12 C.Y. hauler, no haul incl.									
	4000	Common earth, shovel, 1 C.Y. bucket	B-12N	840	.019	C.Y.	3.58	.44	.72	4.74	5.40

B-85

029 | Landscaping

2 SITE WORK

029 200 | Soil Preparation

		029 200 Soil Preparation	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
204	6000	Tilling topsoil, 20 HP tractor, disk harrow, 2" deep	B-66	50,000	.001	S.Y.					.01	204
	6050	4" deep		40,000	.001						.02	
	6100	6" deep		30,000	.001			.01	.01	.02	.02	
	6150	26" rototiller, 2" deep	A-1	1,250	.006			.12	.05	.17	.25	
	6200	4" deep		1,000	.008			.15	.06	.21	.32	
	6250	6" deep		750	.011			.20	.08	.28	.43	
	7000	Lawn maintenance see Division 029-700										
208	0010	PLANT BED PREPARATION										208
	0100	Backfill planting pit, by hand, on site topsoil	2 Clab	18	.889	C.Y.		16.90		16.90	28.50	
	0200	Prepared planting mix	"	24	.667			12.65		12.65	21.50	
	0300	Skid steer loader, on site topsoil	B-62	340	.071			1.44	.28	1.72	2.70	
	0400	Prepared planting mix	"	410	.059			1.20	.23	1.43	2.24	
	1000	Excavate planting pit, by hand, sandy soil	2 Clab	16	1			19		19	32	
	1100	Heavy soil or clay	"	8	2			38		38	64	
	1200	1/2 C.Y. backhoe, sandy soil	B-11C	150	.107			2.31	1.33	3.64	5.25	
	1300	Heavy soil or clay	"	115	.139			3.02	1.74	4.76	6.85	
	2000	Mix planting soil, incl. loam, manure, peat, by hand	2 Clab	60	.267		24	5.05		29.05	35	
	2100	Skid steer loader	B-62	150	.160		24	3.28	.64	27.92	32.50	
	3000	Pile sod, skid steer loader	"	2,800	.009	S.Y.		.18	.03	.21	.33	
	3100	By hand	2 Clab	400	.040			.76		.76	1.28	
	4000	Remove sod, F.E. loader	B-10S	2,000	.006			.14	.16	.30	.39	
	4100	Sod cutter	B-12K	3,200	.005			.12	.26	.38	.48	
	4200	By hand	2 Clab	240	.067			1.27		1.27	2.13	
		029 300 | Lawns & Grasses										
308	0010	SEEDING Athletic field mix, 8#/M.S.F., push spreader R029 -310	A-1	10	.800	M.S.F.	11.80	15.20	5.85	32.85	45	308
	0100	Tractor spreader	B-66	52	.154		11.80	3.60	3.51	18.91	22.50	
	0200	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	0400	Birdsfoot trefoil, .45#/M.S.F., push spreader	A-1	10	.800		13.95	15.20	5.85	35	47.50	
	0500	Tractor spreader	B-66	52	.154		13.95	3.60	3.51	21.06	25	
	0600	Hydro or air seeding,with mulch & fertil.	B-81	80	.300		28.50	6.30	6.90	41.70	49.50	
	0800	Bluegrass, 4#/M.S.F., common, push spreader	A-1	10	.800		5.05	15.20	5.85	26.10	37.50	
	0900	Tractor spreader	B-66	52	.154		5.05	3.60	3.51	12.16	15.20	
	1000	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		19.15	6.30	6.90	32.35	39	
	1100	Baron, push spreader	A-1	10	.800		10.60	15.20	5.85	31.65	43.50	
	1200	Tractor spreader	B-66	52	.154		10.60	3.60	3.51	17.71	21.50	
	1300	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		25.50	6.30	6.90	38.70	46	
	1500	Clover, 0.67#/M.S.F., white, push spreader	A-1	10	.800		2.50	15.20	5.85	23.55	34.50	
	1600	Tractor spreader	B-66	52	.154		2.50	3.60	3.51	9.61	12.40	
	1700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		16.65	6.30	6.90	29.85	36.50	
	1800	Ladino, push spreader	A-1	10	.800		4.23	15.20	5.85	25.28	36.50	
	1900	Tractor spreader	B-66	52	.154		4.23	3.60	3.51	11.34	14.30	
	2000	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		18.20	6.30	6.90	31.40	38	
	2200	Fescue 5.5#/M.S.F., tall, push spreader	A-1	10	.800		7.35	15.20	5.85	28.40	40	
	2300	Tractor spreader	B-66	52	.154		7.35	3.60	3.51	14.46	17.70	
	2400	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		22.50	6.30	6.90	35.70	42.50	
	2500	Chewing, push spreader	A-1	10	.800		8.55	15.20	5.85	29.60	41.50	
	2600	Tractor spreader	B-66	52	.154		8.55	3.60	3.51	15.66	19.05	
	2700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		23.50	6.30	6.90	36.70	43.50	
	2900	Crown vetch, 4#/M.S.F., push spreader	A-1	10	.800		38.50	15.20	5.85	59.55	74.50	
	3000	Tractor spreader	B-66	52	.154		38.50	3.60	3.51	45.61	52	
	3100	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		53	6.30	6.90	66.20	76	
	3300	Rye, 10#/M.S.F., annual, push spreader	A-1	10	.800		4.83	15.20	5.85	25.88	37	
	3400	Tractor spreader	B-66	52	.154		4.83	3.60	3.51	11.94	14.95	
	3500	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		18.25	6.30	6.90	31.45	38	

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

B-86

4) Erosion Control

Used to prevent windblown emission and surface runoff of soil

Silt Fence - Assume Perimeter ~1500 ft

Unit Cost = $0.72/ft

Cost = (1500 ft)($0.72/ft) = $1080 ~ $1000

Polyethylene Sheeting - to cover 10% of Cap Area

Area = 2.5 acres (10%) = 0.25 acres

Unit Cost = $0.34/yd² - 4 mil Polyethylene Sheeting

$$Cost = (0.25 ac)\left(\frac{43560 ft^2}{acre}\right)\left(\frac{yd^2}{9 ft^2}\right)\left(\frac{\$0.34}{yd^2}\right) = \$411 \sim \$500$$

Total Cost = $106,000 + $23,000 + $5000 + $1000 + $500 = $135,500

~ $136,000

$\boxed{\text{Total Cost} = \$136,000}$

Ref.	Line	Description	Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
		022 400 | Soil Stabilization									
412	1030	8" deep	B-74	1,050	.061	S.Y.	1.05	1.35	2.86	5.26	6.4
	1060	12" deep		960	.067		1.57	1.47	3.13	6.17	7.4
	1100	6% mix, 6" deep		1,100	.058		1.15	1.29	2.73	5.17	6.2
	1120	8" deep		1,050	.061		1.50	1.35	2.86	5.71	6.9
	1160	12" deep		960	.067		2.27	1.47	3.13	6.87	8.2
	1200	9% mix, 6" deep		1,100	.058		1.74	1.29	2.73	5.76	6.9
	1220	8" deep		1,050	.061		2.27	1.35	2.86	6.48	7.7
	1260	12" deep		960	.067		3.42	1.47	3.13	8.02	9.50
	1300	12% mix, 6" deep		1,100	.058		2.27	1.29	2.73	6.29	7.50
	1320	8" deep		1,050	.061		3.04	1.35	2.86	7.25	8.55
	1360	12" deep		960	.067		4.54	1.47	3.13	9.14	10.70
	2020	Hydrated lime, for base, 2% mix by weight, 6" deep		1,800	.036		.92	.79	1.67	3.38	4.07
	2030	8" deep		1,700	.038		1.21	.83	1.77	3.81	4.56
	2060	12" deep		1,550	.041		1.76	.91	1.94	4.61	5.45
	2100	4% mix, 6" deep		1,800	.036		1.78	.79	1.67	4.24	5
	2120	8" deep		1,700	.038		2.41	.83	1.77	5.01	5.90
	2160	12" deep		1,550	.041		3.61	.91	1.94	6.46	7.50
	2200	6% mix, 6" deep		1,800	.036		2.70	.79	1.67	5.16	6.05
	2220	8" deep		1,700	.038		3.61	.83	1.77	6.21	7.20
	2260	12" deep		1,550	.041		5.35	.91	1.94	8.20	9.45
		022 500 | Vibroflotation									
504	0010	VIBROFLOTATION									
	0900	Vibroflotation compacted sand cylinder, minimum	B-60	750	.075	V.L.F.		1.62	1.28	2.90	3.92
	0950	Maximum		325	.172			3.74	2.95	6.69	9.05
	1100	Vibro replacement compacted stone cylinder, minimum		500	.112			2.43	1.92	4.35	5.90
	1150	Maximum		250	.224			4.86	3.83	8.69	11.75
	1300	Mobilization and demobilization, minimum		.47	119	Total		2,575	2,025	4,600	6,275
	1400	Maximum		.14	400	"		8,675	6,850	15,525	21,000
		022 700 | Slope/Erosion Control									
702	0010	CUT DRAINAGE DITCH Common earth	B-11L	6,000	.003	L.F.		.06	.09	.15	.18
	0200	Clay and till		4,200	.004			.08	.12	.20	.27
	0250	Clean wet drainage ditch		10,000	.002			.03	.05	.08	.11
704	0010	EROSION CONTROL Jute mesh, 100 S.Y. per roll, 4' wide, stapled	B-1	2,500	.010	S.Y.	.62	.19		.81	.98
	0060	Nylon, 3 dimensional		2,500	.010		3.50	.19		3.69	4.15
	0070	Paper biodegradable mesh		2,500	.010		.04	.19		.23	.34
	0080	Paper mulch	B-64	20,000	.001		.02	.02	.01	.05	.05
	0100	Plastic netting, stapled, 2" x 1" mesh, 20 mil	B-1	2,500	.010		.33	.19		.52	.66
	0200	Polypropylene mesh, stapled, 6.5 oz./S.Y.		2,500	.010		1.63	.19		1.82	2.09
	0300	Tobacco netting, or jute mesh #2, stapled		2,500	.010		.04	.19		.23	.34
→	1000	Silt fence, polypropylene, ideal conditions	2 Clab	1,600	.010	L.F.	.38	.19		.57	.72
	1100	Adverse conditions	"	950	.017	"	.38	.32		.70	.93
	1200	Place and remove hay bales	A-2	3	8	Ton	45	153	52.50	250.50	350
708	0010	RETAINING WALLS Aluminized steel bin, excavation									
	0020	and backfill not included, 10' wide									
	0100	4' high, design A, 5.5' deep	E-2	650	.086	S.F.	13.50	2.22	1.49	17.21	20.50
	0200	8' high, design A, 5.5' deep		615	.091		15.50	2.35	1.58	19.43	23
	0300	10' high, design B, 7.7' deep		580	.097		16.75	2.49	1.67	20.91	24.50
	0400	12' high, design B, 7.7' deep		530	.106		18.10	2.73	1.83	22.66	26.50
	0500	16' high, design B, 7.7' deep		515	.109		19.10	2.81	1.88	23.79	28
	0600	16' high, design C, 9.9' deep		500	.112		20	2.89	1.94	24.83	29
	0700	20' high, design C, 9.9' deep		470	.119		22.50	3.08	2.06	27.64	32.50
	0800	20' high, design D, 12.1' deep		460	.122		23	3.14	2.11	28.25	33.50

R-02

029 300 | Lawns & Grasses

			Crew	Daily Output	Man-Hours	Unit	1994 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
316	1200	1000 S.F.	B-63	16	2.500	M.S.F.	360	49.50	6	415.50	480
	1500	Sloped ground, over 6 M.S.F.		15	2.667		320	53	6.40	379.40	440
	1600	3 M.S.F.		13.50	2.963		350	59	7.10	416.10	485
	1700	1000 S.F.		12	3.333		370	66.50	8	444.50	520
320	0010	STOLENS, SPRIGGING									
	0100	6" O.C., by hand	1 Clab	4	2	M.S.F.	11.50	38		49.50	72.50
	0110	Walk behind sprig planter	•	80	.100		11.50	1.90		13.40	15.65
	0120	Towed sprig planter	B-66	350	.023		11.50	.53	.52	12.55	14.05
	0130	9" O.C., by hand	1 Clab	5.20	1.538		8.50	29		37.50	56
	0140	Walk behind sprig planter	•	92	.087		8.50	1.65		10.15	11.95
	0150	Towed sprig planter	B-66	420	.019		8.50	.45	.43	9.38	10.50
	0160	12" O.C., by hand	1 Clab	6	1.333		5.25	25.50		30.75	46
	0170	Walk behind sprig planter	•	110	.073		5.25	1.38		6.63	8
	0180	Towed sprig planter	B-66	500	.016		5.25	.37	.36	5.98	6.75
	0200	Broadcast, by hand, 2 Bu per M.S.F.	1 Clab	15	.533		4.65	10.15		14.80	21
	0210	4 Bu. per M.S.F.		10	.800		9.10	15.20		24.30	34
	0220	6 Bu. per M.S.F.		6.50	1.231		13.65	23.50		37.15	52
	0300	Hydro planter, 6 Bu. per M.S.F.	B-64	100	.160		13.65	3.07	2.55	19.27	22.50
	0320	Manure spreader planting 6 Bu. per M.S.F.	B-66	200	.040		13.65	.94	.91	15.50	17.45

029 500 | Trees/Plants/Grnd Cover

			Crew	Daily Output	Man-Hours	Unit	Mat.	Labor	Equip.	Total	Total Incl O&P
516	0010	MULCH									
	0100	Aged barks, 3" deep, hand spread	1 Clab	100	.080	S.Y.	1.52	1.52		3.04	4.08
	0150	Skid steer loader	B-63	13.50	2.963	M.S.F.	166	59	7.10	232.10	283
	0200	Hay, 1" deep, hand spread	1 Clab	475	.017	S.Y.	.16	.32		.48	.69
	0250	Power mulcher, small	B-64	180	.089	M.S.F.	17.15	1.71	1.41	20.27	23
	0350	Large	B-65	530	.030	•	17.15	.58	.77	18.50	20.50
	0370	Fiber mulch recycled newsprint hand spread	1 Clab	500	.016	S.Y.	.07	.30		.37	.56
	0380	Power mulcher small	B-64	200	.080	M.S.F.	6.75	1.54	1.27	9.56	11.25
	0390	Power mulcher large	B-65	600	.027	•	6.75	.51	.68	7.94	9
	0400	Humus peat, 1" deep, hand spread	1 Clab	700	.011	S.Y.	.60	.22		.82	1
	0450	Push spreader	A-1	2,500	.003	•	.60	.06	.02	.68	.79
	0550	Tractor spreader	B-66	700	.011	M.S.F.	62.50	.27	.26	63.03	69.50
	0600	Oat straw, 1" deep, hand spread	1 Clab	475	.017	S.Y.	.22	.32		.54	.75
	0650	Power mulcher, small	B-64	180	.089	M.S.F.	24	1.71	1.41	27.12	30.50
	0700	Large	B-65	530	.030	•	24	.58	.77	25.35	28.50
	0750	Add for asphaltic emulsion	B-45	1,770	.009	Gal.	1.50	.20	.38	2.08	2.38
	0800	Peat moss, 1" deep, hand spread	1 Clab	900	.009	S.Y.	.84	.17		1.01	1.19
	0850	Push spreader	A-1	2,500	.003	•	.84	.06	.02	.92	1.05
	0950	Tractor spreader	B-66	700	.011	M.S.F.	91.50	.27	.26	92.03	102
	1000	Polyethylene film, 6 mil.	2 Clab	2,000	.008	S.Y.	.15	.15		.30	.41
	1010	4 mil		2,300	.007		.12	.13		.25	.34
	1020	1-1/2 mil		2,500	.006		.07	.12		.19	.27
	1050	Filter fabric weed barrier		2,000	.008		1	.15		1.15	1.34
	1100	Redwood nuggets, 3" deep, hand spread	1 Clab	150	.053		4.90	1.01		5.91	7
	1150	Skid steer loader	B-63	13.50	2.963	M.S.F.	545	59	7.10	611.10	700
	1200	Stone mulch, hand spread, ceramic chips, economy	B-14	125	.384	S.Y.	5.25	7.70	1.60	14.55	19.70
	1250	Deluxe	•	95	.505	•	7.75	10.15	2.10	20	27
	1300	Granite chips	B-1	10	2.400	C.Y.	25	47		72	103
	1400	Marble chips		10	2.400		95	47		142	180
	1500	Onyx gemstone		10	2.400		280	47		327	385
	1600	Pea gravel		28	.857		16.20	16.85		33.05	44.50
	1700	Quartz		10	2.400		120	47		167	207
	1800	Tar paper, 15 Lb. felt	1 Clab	800	.010	S.Y.	.34	.19		.53	.67
	1900	Wood chips, 2" deep, hand spread	•	220	.036	•	.85	.69		1.54	2.03

SITE WORK 2

B-89

ICF KAISER ENGINEERS

Job No. 0430240300

Sheet 1 of 1

Alternative D: Bioslurry

Treatment Cost

DESIGNED BY RPL DATE 9/1/9?

CHECKED BY ?D? DATE 9/1/9?

$\boxed{\text{Cost} = \$250/\text{ton}}$

Cost includes:

- Equipment: 1 yd^3 backhoe, 12 yd^3 dumptruck, 2 yd^3 front end loader
  Bioslurry reactor, sump pump, monitoring equipment
- Site Work: Clearing and Grubbing, Bulk excavation, Grading, paving, seeding, mulching and cap for bioslurry backfill
- Buildings: Temporary Structures and Liner System
- Mechanical/Piping: Site Drainage and Storm Runoff Control
- Electrical: Equipment Power Distribution. Site Lighting
- Off-site Analytics

Source: Mork Hampton, USAEC, Aberdeen Proving Grounds, MD

ICF KAISER ENGINEERS

Job No. 0430240300

Sheet 1 of 1

Alternative D: Windrow Composting
Bioslurry
Landfill Monitoring

DESIGNED BY RRL DATE 9/1/9

CHECKED BY RDB DATE 9/1/9

1) Monitoring Wells

1 upgradient well - 2 downgradien wells

Unit Cost = \$10,000/well

Cost = (3 wells)(\$10,000/well) = $\boxed{\$30,000}$

2) Well Sampling

Time = 30 years 1st year Quarterly, remainder every 6 Mo.

Unit Cost = \$300/well + \$300/blank

30 year Cost = (1 year)(4 Quarters)(\$1200) + (29 yrs)(2 biannual)(\$1200)

= \$74,400

Annual Cost = $\frac{(\$74,400)}{30 \text{ yrs}}$ = \$2480/yr ~ $\boxed{\$2500/yr}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

ICF KAISER ENGINEERS	JOB No. 04302400?00 SHEET 1 OF 1
Alternative D3 Windrow Composting Bioslurry	DESIGNED BY RPL DATE 9/1/9
Engineered Caps	CHECKED BY RDB DATE 9/1/94

The engineered caps will consist of a 3" layer of binder course asphalt over a 6" layer of gravel. Clearing and grubbing of the contaminated areas will be performed prior to cap placement. The area to be covered with engineered caps is approximately 20,000 ft² for cost comparisons

1) Clearing and Grubbing

Clear area for optional engineered caps. Reduce cost by 40% because trees will be burned at OBG, not chipped.

$$Area = (20,000 ft^2)\left(\frac{1 acre}{43560 ft^2}\right) = 0.46 acres$$

$$Unit\ Cost = (\$2700/acre + \$1200/acre)(60\%) = \$2340/acre$$

Hauling to OBG

Hauling will be a 5 mile round trip with a 12 yd³ dump Truck. Assume 0.5 ft³ of material for every ft² cleared

$$Unit\ Cost = (6.95/yd^3)\left(\frac{1 yd^3}{27 ft^3}\right)\left(\frac{0.5 ft^3}{ft^2}\right)\left(\frac{43560 ft^2}{acre}\right) = \$5606/acre$$

$$Cost = (0.46 acre)(\$2340/ac + \$5606/ac) = \$3655 \sim \$4,000$$

2) 6" Gravel Layer

$$Volume = \left(\frac{6"}{12"/ft}\right)(20,000 ft^2)(1 yd^3/27 ft^3) = 370 yd^3$$

Unit Cost: Load and Haul = $6.30/yd³
Backfill and Compact = $2.02/yd³
$8.32/yd³

$$Cost = (370 yd^3)(\$8.32/yd^3) = \$3078 \sim \$3,000$$

3) 3" Asphalt Layer

$$Area = (20,000 ft^2)\left(\frac{1 yd^2}{9 ft^2}\right) = 2,222 yd^2$$

Unit Cost: $5.25/yd²

$$Cost = (2,222 yd^2)(\$5.25/yd^2) = \$11,666 \sim \$12,000$$

Total Cost = $4,000 + $3,000 + $12,000 = $\boxed{\$19,000}$

CALCULATIONS KE Form No. E-6 Rev. 12-89

SITE WORK 2

	021 100 | Site Clearing		CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
104	0010	CLEAR AND GRUB Light, trees to 6" diam., cut & chip	B-7	1	48	Acre		970	1,075	2,045	2,700	104
	0150	Grub stumps and remove	B-30	2	12			255	740	995	1,200	
	0160	Clear & grub brush & stumps	"	.58	41.379			880	2,550	3,430	4,150	
	0200	Medium, trees to 12" diam., cut & chip	B-7	.70	68.571			1,375	1,525	2,900	3,850	
	0250	Grub stumps and remove	B-30	1	24			510	1,475	1,985	2,400	
	0260	Clear & grub dense brush & stumps	"	.47	51.064			1,075	3,150	4,225	5,125	
	0300	Heavy, trees to 24" diam., cut & chip	B-7	.30	160			3,225	3,575	6,800	9,025	
	0350	Grub stumps and remove	B-30	.50	48			1,025	2,950	3,975	4,825	
	0400	If burning is allowed, reduce cut & chip									40%	
	3000	Chipping stumps, to 18" deep, 12" diam.	B-86	20	.400	Ea.		9.75	7.95	17.70	23.50	
	3040	18" diameter		16	.500			12.20	9.95	22.15	29.50	
	3080	24" diameter		14	.571			13.90	11.35	25.25	34	
	3100	30" diameter		12	.667			16.25	13.25	29.50	39.50	
	3120	36" diameter		10	.800			19.50	15.90	35.40	47.50	
	3160	48" diameter		8	1			24.50	19.85	44.35	59.50	
	5000	Tree thinning, feller buncher, conifer										
	5080	Up to 8" diameter	B-93	240	.033	Ea.		.81	1.42	2.23	2.80	
	5120	12" diameter		160	.050			1.22	2.13	3.35	4.21	
	5240	Hardwood, up to 4" diameter		240	.033			.81	1.42	2.23	2.80	
	5280	8" diameter		180	.044			1.08	1.89	2.97	3.74	
	5320	12" diameter		120	.067			1.62	2.84	4.46	5.60	
	7000	Tree removal, congested area, aerial lift truck										
	7040	8" diameter	B-85	7	5.714	Ea.		115	110	225	300	
	7080	12" diameter		6	6.667			135	128	263	350	
	7120	18" diameter		5	8			162	154	316	425	
	7160	24" diameter		4	10			202	193	395	525	
	7240	36" diameter		3	13.333			269	257	526	705	
	7280	48" diameter		2	20			405	385	790	1,050	
108	0010	CLEARING Brush with brush saw	A-1	.25	32	Acre		610	234	844	1,225	108
	0100	By hand	"	.12	66.667			1,275	485	1,760	2,525	
	0300	With dozer, ball and chain, light clearing	B-11A	2	8			173	410	583	720	
	0400	Medium clearing	"	1.50	10.667			231	545	776	960	
	0500	With dozer and brush rake, light	B-11B	1	16			345	1,025	1,370	1,675	
	0550	Medium brush to 4" diameter		.60	26.667			580	1,725	2,305	2,775	
	0600	Heavy brush to 4" diameter		.40	40			865	2,575	3,440	4,175	
	1000	Brush mowing, tractor w/rotary mower, no removal										
	1020	Light density	B-84	2	4	Acre		97.50	104	201.50	264	
	1040	Medium density		1.50	5.333			130	139	269	350	
	1080	Heavy density		1	8			195	209	404	530	
116	0010	FELLING TREES & PILING With tractor, large tract, firm										116
	0020	level terrain, no boulders, less than 12" diam. trees										
	0300	300 HP dozer, up to 400 trees/acre, 0 to 25% hardwoods	B-10M	.75	16	Acre		360	1,325	1,685	2,000	
	0340	25% to 50% hardwoods		.60	20			450	1,650	2,100	2,525	
	0370	75% to 100% hardwoods		.45	26.667			600	2,225	2,825	3,350	
	0400	500 trees/acre, 0% to 25% hardwoods		.60	20			450	1,650	2,100	2,525	
	0440	25% to 50% hardwoods		.48	25			565	2,075	2,640	3,150	
	0470	75% to 100% hardwoods		.36	33.333			750	2,775	3,525	4,225	
	0500	More than 600 trees/acre, 0 to 25% hardwoods		.52	23.077			520	1,925	2,445	2,900	
	0540	25% to 50% hardwoods		.42	28.571			645	2,375	3,020	3,600	
	0570	75% to 100% hardwoods		.31	38.710			875	3,200	4,075	4,875	
	0900	Large tract clearing per tree										
	1500	300 HP dozer, to 12" diameter, softwood	B-10M	320	.038	Ea.		.85	3.11	3.96	4.73	
	1550	Hardwood		100	.120			2.71	9.95	12.66	15.15	
	1600	12" to 24" diameter, softwood		200	.060			1.35	4.98	6.33	7.60	
	1650	Hardwood		80	.150			3.39	12.45	15.84	18.95	

B-93

The Loading and Hauling of Sand and Gravel System balances the productivity of loading equipment to hauling equipment. It is assumed that the hauling equipment will encounter light traffic and will move up no considerable grades on the haul route.

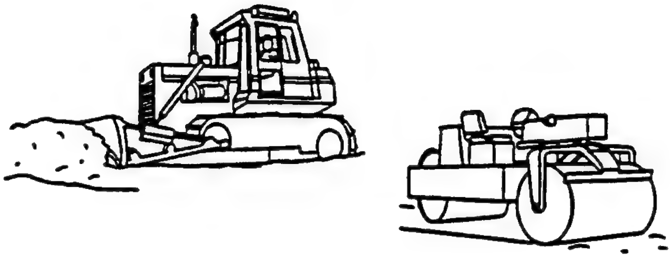
The Expanded System Listing shows Loading and Hauling systems that use either a track or wheel front-end loader. Track loaders indicated range from 1-1/2 Cubic Yards capacity to 4-1/2 Cubic Yards capacity. Wheel loaders range from 1-1/2 Cubic Yards to 5 Cubic Yards. Trucks for hauling range from 12 Cubic Yards capacity to 20 Cubic Yards capacity. Each system lists the number of trucks involved and the distance (round trip) that each must travel.

System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
SYSTEM 12.1-612-1000					
LOAD & HAUL SAND & GRAVEL,1-1/2SFF3 CY LOADER, FOUR 12 CY TRUCKS, 1MRT					
Excavating bulk, F.E. loader, track mtd., 1/2 C.Y.	1.000	C.Y.	.43	.47	.90
Haul earth, 12 C.Y. dump truck, 1 mile round trip, 2.7 loads/hr	1.000	C.Y.	1.94	1.07	3.01
Spotter at earth fill dump or in cut	.040	Hr.		.12	.12
Total			2.37	1.66	4.03

12.1-612	Load & Haul Sand & Gravel	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
1000	Load & haul sand&gravel,1-1/2CY tr.loader,four 12CY dump trucks,1MRT	2.37	1.66	4.03
1200	Six 12 C.Y. dump trucks, 3 mile round trip	3.22	2.23	5.45
1400	Four 16 C.Y. dump trailers, 3 mile round trip	3.13	1.84	4.97
1600	Three 20 C.Y. dump trailers, 2 mile round trip	2.42	1.52	3.94
1800	Four 20 C.Y.dump trailers, 4 mile round trip	3.07	1.81	4.88
2000	2-1/2 C.Y. track loader, six 12 C.Y. dump trucks, 2 mile round trip	2.87	1.92	4.79
2200	Eight 12 C.Y. dump trucks, 4 mile round trip	3.84	2.46	6.30
2400	Five 16 C.Y. dump trailers, 3 mile round trip	3.16	1.71	4.87
2600	Three 20 C.Y. dump trailers, 1 mile round trip	2.06	1.22	3.28
3000	3-1/2 C.Y. track loader, six 12 C.Y. dump trucks, 1 mile round trip	2.58	1.56	4.14
3200	Six 16 C.Y. dump trailers, 2 mile round trip	2.87	1.48	4.35
3600	Eight 16 C.Y. dump trailers, 4 mile round trip	3.57	1.76	5.33
4000	4-1/2 C.Y. track loader, six 16 C.Y. dump trailers, 1 mile round trip	2.37	1.13	3.50
4200	Eight 16 C.Y. dump trailers, 2 mile round trip	2.76	1.30	4.06
4400	Eight 20 C.Y. dump trailers, 3 mile round trip	2.82	1.34	4.16
4600	Nine 20 C.Y. dump trailers, 4 mile round trip	3.11	1.46	4.57
5000	1-1/2 C.Y. wheel loader, four 12 C.Y. dump trucks, 1 mile round trip	2.33	1.65	3.98
5200	Six 12 C.Y. dump trucks, 3 mile round trip	3.18	2.23	5.41
5400	Four 16 C.Y. dump trailers, 2 mile round trip	2.64	1.56	4.20
5600	Five 16 C.Y. dump trailers, 4 mile round trip	3.36	1.90	5.26
6000	3 C.Y. wheel loader, ten 12 C.Y.dump trucks, 3 mile round trip	3.03	1.89	4.92
6200	Five 16 C.Y. dump trailers, 1 mile round trip	2.08	1.11	3.19
6400	Six 16 C.Y. dump trailers, 2 mile round trip	2.51	1.40	3.91
6600	Seven 20 C.Y. dump trailers, 4 mile round trip	2.85	1.52	4.37
7000	5 C.Y. wheel loader, eight 16 C.Y. dump trailers, 1 mile round trip	2.26	1.08	3.34
7200	Twelve 16 C.Y. dump trailers, 3 mile round trip	3.06	1.44	4.50
7400	Nine 20 C.Y. dump trailers, 2 mile round trip	2.36	1.13	3.49
7600	Twelve 20 C.Y. dump trailers, 4 mile round	3.01	1.42	4.43

13-94

See the Reference Section for reference number information, Crew Listings and City Cost Indexes



The Gravel Backfilling System includes: a bulldozer to place and level backfill in specified lifts; compaction equipment; and a water wagon for adjusting moisture content.

The Expanded System Listing shows Gravel Backfilling operations with bulldozers ranging from 75 H.P. to 300 H.P. The maximum hauling distance ranges from 50' to 300'. Lifts for the compaction range from 6" to 12". There is no waste included in the assumptions.

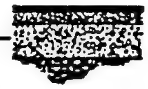
System Components	QUANTITY	UNIT	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
SYSTEM 12.1-722-1000					
GRAVEL BACKFILL, 75 HP DOZER & COMPACTORS,50' HAUL, 6" LIFTS,2 PASSES					
Backfilling, dozer, 75 H.P., 50' haul, sand and gravel, from stockpile	1.000	C.Y.	.27	.38	.65
Water wagon rent per day	.003	Hr.	.20	.09	.29
Compaction, vibrating roller, 6" lifts, 2 passes	1.000	C.Y.	.23	.86	1.09
Total			.70	1.33	2.03

12.1-722	Gravel Backfill	COST PER C.Y. EQUIP.	COST PER C.Y. LABOR	COST PER C.Y. TOTAL
1000	Gravel backfill, 75 HP dozer & compactors, 50' haul, 6"lifts, 2 passes	.70	1.33	2.03
1050	4 passes	1.07	2.25	3.32
1100	12" lifts, 2 passes	.45	.84	1.29
1150	4 passes	.70	1.33	2.03
1200	150' haul, 6" lifts, 2 passes	.97	1.71	2.68
1250	4 passes	1.34	2.63	3.97
1300	12" lifts, 2 passes	.84	1.65	2.49
1350	4 passes	.97	1.71	2.68
1400	300' haul, 6" lifts, 2 passes	1.24	2.08	3.32
1450	4 passes	1.61	3	4.61
1500	12" lifts, 2 passes	.99	1.59	2.58
1550	4 passes	1.24	2.08	3.32
1600	105 HP dozer & vibrating compactors, 50' haul, 6" lifts, 2 passes	.76	1.26	2.02
1650	4 passes	1.13	2.18	3.31
1700	12" lifts, 2 passes	.51	.77	1.28
1750	4 passes	.76	1.26	2.02
1800	150' haul, 6" lifts, 2 passes	1.09	1.58	2.67
1850	4 passes	1.46	2.50	3.96
1900	12" lifts, 2 passes	.84	1.09	1.93
1950	4 passes	1.09	1.58	2.67
2000	300' haul, 6" lifts, 2 passes	1.38	1.85	3.23
2050	4 passes	1.75	2.77	4.52
2100	12" lifts, 2 passes	1.13	1.36	2.49
2150	4 passes	1.38	1.85	3.23
2200	200 HP dozer & roller compactors, 150' haul, 6" lifts, 2 passes	1.08	.59	1.67
2250	4 passes	1.35	.81	2.16
2300	12" lifts, 2 passes	.88	.45	1.33
2350	4 passes	1.08	.59	1.67
2600	300' haul, 6" lifts, 2 passes	1.46	.77	2.23
2650	4 passes	1.73	.99	2.72
2700	12" lifts, 2 passes	1.26	.63	1.89
2750	4 passes	1.46	.77	2.23

See the Reference Section for reference number information, Crew Listings and City Cost Indexes

13-95

025 100 | Walk/Rd/Parkng Paving

		025 100 Walk/Rd/Parkng Paving	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	1994 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
104	0080	Binder course, 1-1/2" thick	B-25	7,725	.011	S.Y.	1.99	.24	.21	2.44	2.79
	0120	2" thick		6,345	.014		2.65	.29	.25	3.19	3.65
	0160	3" thick		4,905	.018		3.94	.37	.33	4.64	5.25
	0200	4" thick 		4,140	.021		5.25	.44	.39	6.08	6.90
	0300	Wearing course, 1" thick	B-25B	10,575	.009		1.44	.19	.17	1.80	2.07
	0340	1-1/2" thick		7,725	.012		2.18	.26	.24	2.68	3.07
	0380	2" thick		6,345	.015		2.93	.32	.29	3.54	4.05
	0420	2-1/2" thick		5,480	.018		3.62	.37	.33	4.32	4.92
	0460	3" thick		4,900	.020		4.31	.41	.37	5.09	5.80
	0800	Alternate method of figuring paving costs									
	0810	Binder course, 1-1/2" thick	B-25	630	.140	Ton	26	2.88	2.56	31.44	36
	0811	2" thick		690	.128		26	2.63	2.34	30.97	35
	0812	3" thick		800	.110		26	2.27	2.02	30.29	34.50
	0813	4" thick		900	.098		26	2.02	1.79	29.81	33.50
	0850	Wearing course, 1" thick	B-25B	575	.167		26.50	3.50	3.19	33.19	38.50
	0851	1-1/2" thick		630	.152		26.50	3.19	2.91	32.60	37.50
	0852	2" thick		690	.139		26.50	2.91	2.66	32.07	37
	0853	2-1/2" thick		745	.129		26.50	2.70	2.46	31.66	36.50
	0854	3" thick		800	.120		26.50	2.51	2.29	31.30	36
	1000	Pavement replacement over trench, 2" thick	B-37	90	.533	S.Y.	1.47	10.70	1.50	13.67	20
	1050	4" thick		70	.686		6.45	13.75	1.93	22.13	30.50
	1080	6" thick		55	.873		9.95	17.50	2.46	29.91	41
108	0010	ASPHALTIC CONCRETE At the plant (145 lb. per C.F.) R025-110				Ton	23.50			23.50	26
	0200	All weather patching mix					26.50			26.50	29
	0300	Berm mix					26.50			26.50	29
	0400	Base mix					23.50			23.50	26
	0500	Binder mix					23.50			23.50	26
	0600	Sand or sheet mix					27.50			27.50	30
	2000	Reclaimed pavement in stockpile					9.55			9.55	10.50
	2100	Recycled pavement, at plant, ratio old: new, 70:30					19.15			19.15	21
	2120	Ratio old: new, 30:70					23.50			23.50	26
112	0010	CALCIUM CHLORIDE Delivered, 100 lb. bags, truckload lots				Ton	310			310	340
	0200	Solution, 4 lb. flake per gallon, tank truck delivery				Gal.	.62			.62	.68
116	0010	COLD LAID ASPHALT PAVEMENT 0.5 gal. asphalt/S.Y. per in. depth									
	0020	Well graded granular aggregate									
	0100	Blade mixed in windrows, spread & compacted 4" course	B-90A	1,600	.035	S.Y.	3.67	.78	.92	5.37	6.25
	0200	Traveling plant mixed in windrows, compacted 4" course	B-90B	3,000	.016		3.67	.35	.46	4.48	5.10
	0300	Rotary plant mixed in place, compacted 4" course	•	3,500	.014		3.67	.30	.40	4.37	4.95
	0400	Central stationary plant, mixed, compacted 4" course	B-36	7,200	.006		7.35	.12	.15	7.62	8.40
120	0010	CONCRETE PAVEMENT Including joints, finishing, and curing									
	0020	Fixed form, 12' pass, unreinforced, 6" thick	B-26	3,000	.029	S.Y.	13.50	.62	.60	14.72	16.50
	0030	7" thick		2,850	.031		16.10	.65	.63	17.38	19.45
	0100	8" thick 		2,700	.033		18.15	.69	.66	19.50	22
	0200	9" thick		2,900	.030		20.50	.64	.62	21.76	24
	0300	10" thick		2,100	.042		22.50	.89	.85	24.24	27
	0400	12" thick		1,800	.049		27	1.04	.99	29.03	32
	0500	15" thick		1,500	.059		33.50	1.24	1.19	35.93	40.50
	0510	For small irregular areas, add						100%		100%	
	0600	For continuous welded steel reinforcement over 10' wide, add				S.Y.				4.30	
	0610	Under 10' wide, add								6.45	
	0700	Finishing, broom finish small areas	2 Cefi	135	.119			2.76		2.76	4.13
	0730	Transverse expansion joints, incl. premolded bit. jt. filler	C-1	150	.213	L.F.	1	4.82	.18	6	8.95
	0740	Transverse construction joint using bulkhead	•	73	.438	•	1.45	9.90	.38	11.73	17.70
	0750	Longitudinal joint tie bars, grouted	B-23	70	.571	Ea.	2.25	11.10	8.40	21.75	29.50
	1000	Curing, with sprayed membrane by hand	2 Clab	1,500	.011	S.Y.	.15	.20		.35	.49

B- 96

APPENDIX C

RESULTS OF PREVIOUS INCINERATION STUDIES

Previous Incineration Studies

Previous studies have demonstrated that incineration of explosives-contaminated soil can be performed effectively (USAEC, 1984). Tests were performed with soils collected from Savanna Army Depot Activity (SADA) and Louisiana Army Ammunition Plant (LAAP). Actual testing of the incineration process occurred at SADA. The soils were selected to represent a wide range of physical characteristics and contaminant loadings. The SADA soil was a dry, sandy soil, while the LAAP soil was a moist, clay-based soil. Although the average densities, elemental contents, and percent ash of the SADA and LAAP soils were approximately equal, differences in heating value, moisture content, and explosives concentrations were found to affect the incineration process.

The SADA soil was contaminated with high concentrations of TNT and small amounts of RDX, TNB, DNB, 2-Amino-4,6-Dinitrotoluene (2-A-4,6-DNT), and metals. The LAAP soil was contaminated with substantially higher concentrations of HMX and RDX, higher concentrations of 2-A-4,6-DNT and metals, and lower concentrations of TNT, DNB, and TNB than the SADA soil. The concentrations of explosives compounds found in the soils from the two sites are summarized in Table C-1.

A preliminary test run was conducted to determine whether explosives compounds would be detectable in the stack gas. The temperature and feed rate for the test run were 800°F and 500 lb/hr, respectively. Even though explosives compounds were not detected in the stack gas, the following observations were made:

- Explosives compounds were detected in the ash (6.48 ppm);
- Explosives compounds were detected in the flue gas entering the secondary combustion chamber (195.9 ppm); and
- Explosives compounds were detected in the fly ash (26.27 ppm).

As a result, all subsequent tests were conducted at feed rates between 300 to 400 lb/hr, with primary kiln temperatures ranging from 1200°F to 1600°F. Following industrial practice, the secondary combustion chamber was operated at 400°F above the primary kiln temperature to provide cost-effective auxiliary fuel utilization consistent with effective destruction of flue gas contaminants (e.g., carbon monoxide, hydrocarbons). The auxiliary fuel used to fire the primary kiln and secondary combustion chamber was propane with a heating value of approximately 2,500 Btu/ft^3.

In order to ensure complete combustion of the explosives compounds during the test runs, an ample residence time within the primary kiln was provided. The rotation of the primary kiln was held constant at four revolutions per hour. Since the feed rates were varied between 300 and 400 lb/hr, this rotation rate corresponds to a residence time in the primary kiln of approximately one to two hours. To further guarantee that the explosives compounds in the soil were totally oxidized, air was supplied at rates of 100 to 200 percent above the stoichiometric ratio in the primary kiln and 100 percent above the stoichiometric ratio in the secondary combustion chamber. The use of excess air also helped to control the formation of nitrogen oxides (NO_x).

The NO_x concentration in the stack gas may have an important impact upon the use of incineration since considerable regulatory focus will be directed at evaluating the potential increases in ambient NO_x concentrations. The emission rate of NO_x is closely correlated to the explosives concentration in soil and the soil feed rate. Intuitively, one might expect a strong correlation between thermal NO_x formation and kiln operating temperature. However, the key factor affecting thermal NO_x formation is flame temperature, not combustion chamber temperature. Thermal NO_x was controlled to low levels for all runs by controlling the amount of excess air supplied to the burner nozzles. A stoichiometric feed rate of propane to air produced a flame temperature of about 3,000°F, which resulted

Table C-1. Explosives Concentrations for Incineration Study Feed Soil

Site	HMX (μg/g)	RDX (μg/g)	TNB (μg/g)	DNB (μg/g)	2-A-4,6-DNT (μg/g)	TNT (μg/g)
Savanna Army Depot Activity	ND	28.6 - 145	90.7 - 256	5.5 - 35	ND - 27.9	88,100 - 406,000
Louisiana Army Ammunition Plant	6,180 - 13,500	33,100 - 96,500	57 - 155	9.78 - 22.4	ND - 588	55,100 - 142,000

ND = Not present above method detection limits (Detection limits not reported in the referenced document).

in relatively high thermal NO_x formation. Whereas providing ten percent excess air to the burner nozzles, decreased the flame temperatures to approximately 2,200°F; thereby substantially reducing NO_x formation.

Table C-2 summarizes the concentrations of explosives compounds found in the primary kiln ash. According to the test results, a primary kiln temperature of 1400°F must be used in order to achieve complete destruction of all explosives compounds except TNT. At this temperature, the minimum destruction removal efficiency (DRE) for the SADA soil was 99.999%. Because of its higher moisture content, a primary kiln temperature of 1600°F was used to treat the LAAP soil. At this temperature, the minimum DRE was 99.979%. Even though this value is below the required DRE of 99.99%, incineration is still a viable alternative since no explosives compounds were detected in the stack gas. The use of a secondary combustion chamber ensured the complete destruction of all explosives compounds in the off gas from the primary kiln for both the SADA and LAAP soils.

The fly ash was collected from the fabric filter bags before and after each test run using a compressed air, pulsed-jet cleaning system. However, there was no assurance that the ash removed from the hopper directly corresponded to the respective test run. This is illustrated in Table C-3 by the HMX concentration found in the fabric filter ash from the treatment of the SADA soil. As given in Table C-1, no HMX was found in the SADA feed soil. Therefore, breakthrough of explosives compounds must have occurred during the preliminary test run and contaminated the fabric filter bags.

The primary kiln and fabric filter ash generated during the incineration of the SADA and LAAP soil did not fail EPA's characteristic tests for ignitability, corrosivity, or reactivity. Furthermore, the metals concentrations did not cause the ash to fail the Extraction Procedure (EP) toxicity test. Therefore, in accordance with 40 CFR Section 261, the ash did not exhibit any of the characteristics of a hazardous waste. Because the ash was not considered hazardous, the cost of disposal in a hazardous waste landfill was eliminated. This was beneficial because the incineration process generated approximately 0.4 to 0.8 pounds of ash per pound for SADA and LAAP soil treated. In addition, due to the lower relative density of the primary kiln ash (SADA: 79 - 92 lb/ft^3; LAAP: 43 - 60 lb/ft^3) compared to the feed soil, the actual volume reduction ranged from approximately 50 percent to a slight volume increase (USAEC, 1984).

The economics of on-site incineration are affected by a number of factors other than the quantity of waste, the physical form of the waste, and the contaminant concentrations within the waste. Waste-specific factors must be considered during the project design and cost estimation stages. These characteristics include: heating value, moisture content, halogen content, sulfur content, phosphorus content, alkali metals content, and toxic metals content.

Heating Value. The heating value of a solid waste (e.g., soil) usually has the greatest impact on waste throughput rate and incinerator O&M cost. The higher throughput rates and lower per-ton operating costs are achieved with low Btu soils. The lower throughput rates and highest operating costs are associated with high Btu soils.

Moisture Content. The moisture content of soil also has an impact on the throughput rate and cost of incineration. High soil moisture content reduces throughput rate and increases fuel consumption per ton of soil burned. High soil moisture contents can also cause thermal shocking of refractory brick at the kiln inlet and ignition quenching at the beginning of the volatiles burnout zone. The ignition quenching phenomena has a negative effect on the solids time-temperature profile in the kiln and can reduce the organics burnout efficiency.

Halogen Content. Organic halogens are commonly present in contaminated materials at hazardous waste sites. Organic chlorine, bromine and fluorine are converted into the acids HCl, HBr, and HF, respectively, in the combustion process. With the organic halogen concentrations normally found at waste sites, quantitative conversion to acids can be achieved at secondary combustion chamber

Table C-2. Explosives Concentrations in Primary Kiln Ash from Incineration Study

Site	HMX ($\mu g/g$)	RDX ($\mu g/g$)	TNB ($\mu g/g$)	DNB ($\mu g/g$)	2-A-4,6-DNT ($\mu g/g$)	TNT ($\mu g/g$)	DRE (%)[1]
Savanna Army Depot Activity	ND	ND - 5.21	ND	ND	ND	ND - 8.78	99.992 - 100
Louisiana Army Ammunition Plant	ND	ND	ND - 2.47	ND	ND	ND - 26.9	99.955 - 100

ND = Not present above method detection limits (Detection limits not reported in the referenced document).
[1] Destruction Removal Efficiency (DRE) was based on TNT concentration. Calculated DREs are less than 100% because the calculated value assumes ND=0.

Table C-3. Explosives Concentrations in Fly Ash from Incineration Study

Site	HMX (µg/g)	RDX (µg/g)	TNB (µg/g)	DNB (µg/g)	2-A-4,6-DNT (µg/g)	TNT (µg/g)
Savanna Army Depot Activity	ND - 5.02	ND - 1.57	ND - 5.17	ND - 0.85	ND	ND - 155
Louisiana Army Ammunition Plant	ND - 1.61	ND	ND - 3.66	ND - 0.73	ND	ND - 4.24

ND = Not present above method detection limits (Detection limits not reported in the referenced document).

temperatures of 2,000°F or higher. The acid must then be scrubbed from the flue gas in the downstream air pollution control equipment. Only wet scrubbing systems designed for alkaline operation with caustic soda are effective in removing HBr.

Sulfur Content. Sulfur is a common constituent of contaminated materials at hazardous waste sites. Sulfur is converted to SO_2 and lesser quantities of SO_3 in the combustion process which is removed from the flue gas by wet scrubbing.

Phosphorus Content. Organic phosphorus is converted to P_2O_5 in the combustion process, which condenses to form a sub-micron particle upon cooling. Exposure to water in the scrubbing system forms H_3PO_4 aerosol. Corrosion is a concern, but the biggest problem in burning phosphorus contaminated soil is particulate emissions, because P_2O_5 is difficult to scrub since it has a mean diameter of less than 0.7 μm.

Alkali Metals Content. Sodium or other alkali metals in waste materials can create several problems in the combustion process: severe refractory attack, heat transfer surface fouling, and formation of sub-micron particulates. The refractory attack is a result of sodium reaction with silica in the brick to form low-melting sodium silicate glass at the refractory surface. This material is readily eroded by the movement of the ash charge through the kiln, exposing new surface to attack and continuing the degradation process. Usually high alumina firebrick or phos-bonded plastic are used to increase the resistance to alkalis and acids. However, these types of kilns are more expensive and add significantly to the installation and maintenance costs.

The low fusion temperatures of alkali metal salts lead to extreme fouling problems on the convective heat transfer surfaces of incineration systems equipped for waste heat recovery. These fouling problems can be so acute that the economics of the incineration process are compromised by excessive downtime for boiler surface cleaning.

The volatility of alkali metal salts also causes problems with respect to sub-micron particle formation. Salts vaporized in the primary kiln and secondary combustion chamber recondense homogeneously in the cooler downstream equipment to form particles as small as 0.1 μm in diameter.

Toxic Metals Content. The presence of toxic metals can substantially increase the cost for on-site incineration by requiring additional fine particulate control to prevent metals emissions from the stack, and requiring solidification of the incinerator ash. Volatile toxic metals can be vaporized in the primary kiln and secondary combustion chamber and subsequently condensed as very fine particulates in the scrubbing system. This presents a sub-micron particulate emission problem similar to that of P_2O_5, with the added concern of particle toxicity. The metals of primary concern are mercury, selenium, arsenic, antimony, cadmium, and lead, all of which are volatile at combustion chamber temperatures.

A second, potentially more costly problem with toxic metals is that they remain in the incinerator ash in a form susceptible to leaching as determined by the EP toxicity test. Failure of the EP toxicity test can preclude on-site backfilling of the incinerator ash and in many cases causes on-site incineration to become an uneconomical treatment alternative. Unfortunately, the leaching characteristics of metals in incinerator ash are difficult to predict because they depend on case-specific factors such as the ash matrix, the chemical forms of the metallic species in the feed soil, and the kiln operating conditions.